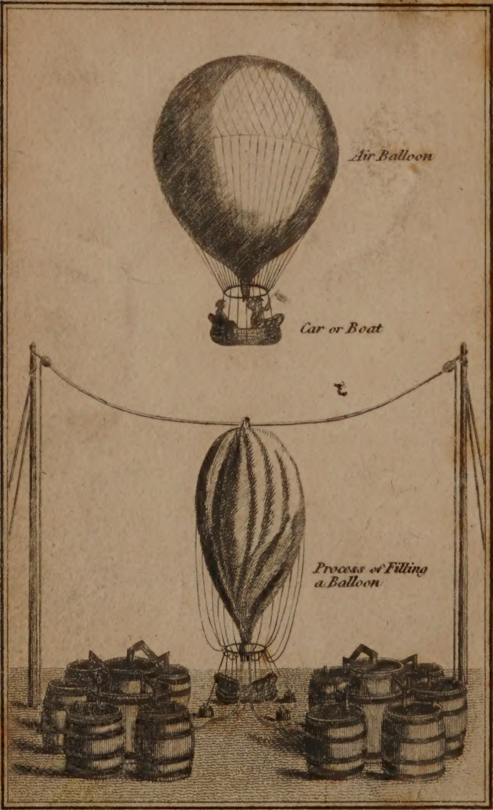
Plate 3.

to face page 257.



Engraved for Pinnock & Maunders Elements of Nat. & Ex. Phil. by Sid^y Hall.

THE

ELEMENTS

OF

NATURAL AND EXPERIMENTAL PHILOSOPHY;

Illustrated by

One Hundred and Twenty-Four Engravings

ON COPPER AND WOOD:

FOR

THE USE OF SCHOOLS AND PRIVATE EDUCATION.

BY THE REV. JOHN BARCLAY,

AUTHOR OF "ELEMENTS OF SCIENCE AND ART:" ALSO, "ELEMENTS OF POLITE LITERATURE."

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PREFACE.

This volume is presumed to be the sequel to the *Elements of Polite Literature*, and the *Elements of Science and Art*. For its first grand division, which embraces the Elements of Natural Philosophy, may be considered as the legitimate companion of the *Elements of Polite Literature*; while the remaining part of the volume connects it immediately with the *Elements of Science and Art*. But from the manner in which the subjects are treated, each is independent of the other, though, taken as a whole, they have that mutual relation which one branch of knowledge, like any individual link of a chain, has with all those that precede or follow its acquisition. Thus, the three works may be studied as a whole, in which case

they make a complete Encyclopedia of Useful Knowledge, or they may be studied separately, as any particular branch of their Literature, Science, Arts, or Philosophy may be desired. And the manner in which the Author has endeavoured to present his ELEMENTS of PHILOSOPHY to youth is equally favourable to the prosecution of this plan. For the subdivision of every Chapter into distinct Sections, of separate portions of the subject, reduces the whole into short and easy lessons: and the Questions, formed on the successive Sections, adapt them to classes in schools, or the conversational communication of knowledge in the retirement of domestic instruction.

The Publishers feel the fullest confidence that this volume presents to youth sound and acknowledged Philosophy, illustrated by entertaining Experiments and Examples. For while the Author has laid open to the young mind numerous

stores of knowledge, his every expression is clothed in language conducive to virtue. And this is no minor advantage in a book destined for youth, in that period of life when they receive implicitly whatever wears the appearance of plausibility.

But these Elements recommend themselves to the public by the following consideration. They are wholly conversant with the productions of Nature and her laws, with the application of those laws to the progress of civilization and the intellectual improvement of our species, and to numerous discoveries which time has communicated for the comfort and happiness of the present and future generations of our race. In a word, at every step in the prosecution of a rational and enlightened System of Natural and Experimental Philosophy, the student is adding to his stock of knowledge by the acquisition of

new facts and ideas. As these burst upon his understanding, he is encouraged to go on in new and untried paths; and he finds in the end that his diligence is rewarded by the superiority which his knowledge gives him over others who have not enjoyed his advantages.

Though the facts and observations which philosophy and science disclose for the improvement and happiness of our species be an universal property, in which every writer has a title, when his labours conduce to the benefit of society, by novelty of arrangement and felicity of application; the author has to acknowledge, in common with others, many obligations to the writings of his predecessors, Ferguson, Buffon, and Imison; and among his contemporaries, to Mr. Brande and Sir Humphry Davy.

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THE ELEMENTS

OF

NATURAL AND EXPERIMENTAL

PHILOSOPHY.

CHAPTER I.

INTRODUCTION TO NATURAL HISTORY.

1. The study of Natural History consists in the collection, arrangement, and exhibition of the various productions of the earth. These productions are divided into three great kingdoms of nature, the mineral, the vegetable, and the animal.

2. Of the three classes of NATURAL HISTORY—*animals*, *vegetables*, and *minerals*—that of animals exhibits the most illustrious marks of wisdom and design, though the other two are not destitute of conspicuous specimens of the same qualities.

Illus. 1. ANIMALS possess the power of *self-motion*, of *sensation*, of seeking and appropriating *nourishment* Their organs are more complicated, and their changes more rapid, than those of vegetables. Some vegetables possess a degree of irritability. They contract on the ap-

plication of stimuli. Few, however, are gifted with this power, far the greater number being susceptible of no movement, except what results from the elasticity of their roots, branches, and leaves. They have not, like animals, any feeling of pleasure or pain; and they can only imbibe nourishment from those parts of matter with which they are in permanent contact.

2. But though these differences are conspicuous in the greater part of animals and vegetables, yet in the lower species of the former, and in the highest species of the latter, they in a great measure disappear; and it is difficult to determine where the class of animals terminates, and that of vegetables begins. The polypus, which generates as many animals of its kind, as are the parts into which it may be divided, seems not to be endowed with a much higher degree of vitality, than that which is possessed by many vegetables.

3. Both in the animal and vegetable kingdom, the smaller species are more numerous than the larger. Thus, there are many more insects than there are men: the plants of grass are more numerous than the trees; and the number of flies surpasses that of horses.

4. As animals descend to vegetables, so the latter approach minerals. Minerals are called inorganized, or inanimate bodies. They seem to compose the mass of the globe; certainly, at least, its external crust. They increase in volume; but this seems to arise entirely from the juxtaposition of parts, and the force of attraction, or that assimilating power of nature which generates from different combinations of the same materials, parts of such different constitutions and uses. The ascent of juices in vegetables seems to depend on the principles by which water rises in capillary tubes. Vegetables grow with a rapidity palpable and conspicuous. In a short space of time many of them reach perfection, after which they suffer decay, and finally dissolution. The growth and decay of minerals is so slow and imperceptible, as to render it sometimes doubtful whether they are susceptible of these qualities. Vegetables have organs by which they elaborate the nourishment at

tracted from the earth and the air. Minerals seem to undergo no change but what arises from the chemical action of bodies on one another.

1. In considering the animal kingdom we will begin with man, "the noblest work of God;" and in any outline of the study of our species we could present, the most scientific will be that which considers him *first*, *generally*, as constituting a tribe of animals differing from all others, in his structure, functions, diseases, and in possessing the faculty of reason: secondly, we may consider him *specifically*, as differing from others of the same tribe in *height*, *features*, *colour*, *disposition*, and *manners*, resulting from climate and other local circumstances: *thirdly*, as a dependant and an accountable being, in relation to his Creator, his *neighbour*, and *himself*: *lastly*, we may consider him with respect to the relations that subsist between him and the inferior classes of the creation, as they minister to his necessities, supply his wants, abridge his comforts, or oppose his progress.

Obs. The first of these views will lead us, in conjunction with what engages his reason, and has been handled in the "Elements of Polite Literature," to consider in this volume the sciences on which the civilization of the species greatly depends.

3. The third view we have taken of man, led, in the "Elements of Science and Art," to the consideration of *Morals* and *Religion*, *Law* and *Government*, with the arts of civilized life. The second and last will therefore fall to be considered in this place.

Questions for Examination.

1. In what does the study of Natural History consist?
2. How do animals exhibit the most illustrious marks of wisdom?
3. Whence do we place man at the head of the animal kingdom? and how are we to consider his Natural History?—

Observation. Previously, however, to our entrance upon the subject before us, the following definitions of science, and the distinction between it and an art, will serve to give the pupil correct ideas of each.

Defin. 1. Science is the knowledge of general rules and their applications.

A general rule is the expression of what is common in a number of particular cases; and general rules are the result of *observation* or of *will*, and must consequently be derived from mind.

Defin. 2. A *science* then, is a system of general truths relative to some branch of human knowledge.

Defin. 3. An art is the application of knowledge to practice.

A science is addressed to the understanding: an art occupies both the understanding and the members of the body.

Note. These matters are fully defined and discussed in the first Chapter of "Elements of Science and Art," to which we must here refer the student.

CHAPTER II.

THE NATURAL HISTORY OF MAN.

SECTION I.

1. THE HISTORY of the human species contains the following arrangements:—

1. THE FORM AND ASPECT OF MAN.
2. HIS RESIDENCE, AND MANNER OF SUBSISTENCE.
3. THE VARIETIES OF HIS RACE.
4. THE PERIOD OF HIS LIFE.
5. HIS DISPOSITION TO SOCIETY.
6. POPULATION IN THE GENERATIONS AND NUMBERS OF MANKIND.
7. VARIETIES OF CHOICE AND PURSUIT.
8. ARTS AND COMMERCE.
9. DISPARITIES OF RANK AND ESTIMATION.
10. POLITICAL ESTABLISHMENTS.
11. LANGUAGE AND LITERATURE.

SECTION II.

Of the Form and Aspect of Man.

1. The HUMAN FORM is *erect*, furnished with *articulations* and *muscles*, fitted to retain this posture, and to move it with ease and safety.

2. The HAND and the ARM of man is an *instru-*

ment and a *weapon*, not a prop or support to his body.

3. His FORM and POSTURE are well fitted to *observation*, to the use of *reason*, and to the practice of *arts*.

4. His ASPECT is expressive of his *thoughts*, *sentiments*, and *intentions*. It is calm or agitated; mild or fierce; languid or ardent; doubtful or decided; timid or intrepid.

5. His NATURAL EXPRESSIONSS consist of *actions gestures*, *smiles*, *frowns*, *tears*, *looks*, together with *changes of colour;* and exhibit, on the whole, a variety, and a grace, which either do not take place, or are not observable in other animals.

6. He is NAKED and UNARMED; but by his *invention*, qualified to supply these defects.

7. The FINAL CAUSE for this appears to be, that his talent for invention should be employed.

Note. CAUSES are of two kinds, *efficient* and *final*.

1. The EFFICIENT CAUSE is the energy or power producing an effect. And in every operation we consider *that* as the cause which precedes or attends the operation, and to which *the effect is always proportional.*

2. The FINAL CAUSE, is the *end* or *purpose* for which an effect is produced. And in supposing *final causes,* we suppose the *existence of mind.*

Questions for Examination.

1. Describe the human form. 2. The use of the hand and arm. 3. For what our form and posture are fitted. 4. Of what our aspect is expressive. 5. In what natural expressions consist. 6. How man supplies his defects. 7. And what the final cause appears to be?

Section III.

Man's Residence and Manner of Subsistence.

1. Other Animals have their ranges on the earth, beyond which they do not willingly rove, or beyond which they are not qualified to subsist.

2. Some subsist only in the *hot* climates, others in the *cold* or temperate; but MAN resides equally in every climate, and can subsist on great varieties of food, both animal and vegetable.

3. He either accommodates himself to the inconveniences of his situation, or he learns by experience to surmount them.

Questions for Examination.

How are some animals restricted on the earth? 2. How do some subsist? 3. And how does man subsist?

Section IV.

Varieties of the Human Race.

1. Under the general form and aspect of mankind, there are considerable VARIETIES of the race.

2. Men being dispersed over the face of the earth, receive the influence of climate, situation, and soil.

3. The animal and rational temperament is comparative, *phlegmatic* and *dull* in *cold climates;* is more *ardent* and *quick* in *warm climates;* but has always possessed a distinguished superiority in the temperate.

4. Apart from these distinctions, the diversities of race are marked by difference of *stature, features*, and *complexion*.

5. Mankind may be referred to six different races:

1. THE EUROPEAN,	4. THE HINDOO,
2. THE SAMOEIDE,	5. THE NEGRO,
3. THE TARTAR,	6. THE AMERICAN.

6. THE EUROPEANS have in general a *clear complexion*, which is thence the best adapted to express the passions of the soul, and to indicate the health of the constitution. They are also, for the most part, characterized by *blue eyes, light hair*, and well proportioned limbs.

Obs. All the European race of Scandinavian origin are so. On the other hand, Europeans, of mixed origin, vary in various degrees, from the clear complexion to the swarthy. This last distinguishes those of Celtic origin, with black hair, black eyes, &c. The Swedes, Germans, Scots, English, and Irish, are of the first, or Scandinavian class of the European race: the Spaniards, the French, the Italians, and the aboriginals of Turkey in Europe, are of the second or swarthy class.

7. THE SAMOEIDES are a large family, very distinctly characterized by a deep *brown colour*, inclining to black, by *short statures*, and *hideous countenances*. Their colour and stature are the effects of climate, and modes of living, and their expression of countenance is a consequence of the savage lives they lead. In this family we include the LAPLANDERS, the ESQUIMAUX, the GREENLANDERS, the NOVA ZEMBLANS, the inha-

bitants of the northern regions of the RUSSIAN empire, and the people of KAMSCHATKA.

Obs. The tallest of these never exceed five feet: their *heads* are *large;* their *cheek-bones highly set;* their *eye-lids* are usually drawn aside; their *mouths* extend almost the breadth of their face; their *lips* are very thick, and pout greatly. They, notwithstanding, reckon themselves handsome, and civilized. The climate they inhabit is cold, barren, and dreary, and their food precarious, consisting of fish, the flesh of bears, rein-deer, and other animals of the frigid zone.

8. THE TARTAR is the next variety. In this race we include all those who inhabit the central regions of Asia, from the shores of China to the Caspian Sea. The Tartar has a *broad forehead*, a *narrow chin*, *small sunk eyes*, *high cheek bones*, a *short* and *flat nose*, *large* and *disunited teeth*, a *short broad stature*, and an *olive complexion*.

Obs. Except in Japan and China, this family has no settled abode, but roves from place to place, pasturing its flocks and herds in the most fertile plains, and defending itself, in a moveable tent, from the inclemency of the weather.

9. THE HINDOO tribes have *swarthy countenances* that approach the European Celts, long straight *black hair*, *slender shapes*, and are generally elegantly limbed.

Obs. Their food consists of rice and fruits. Flesh meat they never eat, their religion prohibiting its use to man. But on the other hand they enjoy health and longevity; their manners are effeminate, but their style of dress is elegant, and the mansions of the wealthy Hindoos are magnificent.

10. The Negro race are *black*, have *woolly heads, flat noses, thick lips;* and are generally well proportioned, and of good strength. Their colour is an effect of their climate.

Obs. This race inhabit the central and southern parts of Africa, and they are for the most part uncivilized, though according to travellers, there are many large and populous cities in the interior of that vast continent.

11. The American, native Indians, a distinct family, were scattered in petty tribes over the whole of that vast continent. They still exist in considerable numbers, and are easily recognized from their *dark copper colour*, their *jet black hair*, their *small eyes*, their *high cheek bones*, and *flat noses*.

Obs. Living, as we find them in North America, a wandering life, their subsistence is almost always precarious, because it depends solely on their address in the use of the bow and the spear; though for some generations, from their intercourse with the Europeans, who have supplanted them in the soil, many tribes of American Indians are expert in the use of the musket. Their clothing consists chiefly of the skins of beasts, like that of all savages, and vegetable products that require the intervention of art to render them subservient to the use of rude dress; their habitations are huts or wigwams.

Questions for Examination.

1. What are there under the general *form* and *aspect* of mankind? 2. What *influence* do men receive? 3. What of the animal and rational *temperament* in different climates? 4. By what *differences* of the race are mankind marked? 5. To what *races* may mankind be referred? 6. Describe at large the *Europeans*. 7. Also the

Samoeide. 8. Likewise the *Tartar.* 9. Also the *Hindoo.* 10. Likewise the *Negro.* 11. And finally the *American.*

Section V.

The period of Human Life.

1. Every SPECIES *of Animal* is preserved by *succession.* The death of one generation is as much a part of the order of nature, as the birth and succession of another.

Note. A *generation* is estimated a period of thirty years.

2. In the *human species,* according to some observations, half the numbers that are born die before the seventeenth, the seventh, or even the third year of their age is expired.

3. In all climates, *long life* extends from between *seventy* to an *hundred years.*

4. It appears, from the annual register of deaths, where the numbers of people are known, that about *one in thirty dies each year*;—that of twenty-seven, or twenty-eight, *one is born*;—that about a *fourth* of the whole number *are males* between eighteen and fifty-six, able to bear arms.

Questions for Examination.

1. How is every species of animals preserved? 2. What is observed of the period of life among the human species? 3. What is the period of long life? 4. What is observed from the annual register of deaths?

SECTION VI.

Disposition of Man to Society.

1. ANIMALS have been distinguished into two classes, the *solitary* and the *social.*

2. *Animals of prey* are for the most part *solitary;* as the *lion* and the *eagle;* the former being usually lord of one forest; while the latter shares with no other bird the mountain it commands.

3. Other animals are for the most part *associating,* and may further be divided into two kinds :—

I. Those which assemble in *flocks* or *herds* merely for *company* or *safety;* as birds, fishes, and quadrupeds of different species.

Example. Thus we have seen flocks of crows, shoals of herrings, and herds of deer.

II. Those that *unite their labours* for some common purpose, and distribute the burdens of the community according to some rule of instinct or reason.

Example. These are both associating and political. And man, though originally an animal of prey, and, from necessity or sport, addicted to hunting or to war, is, nevertheless, in the highest degree associating and political.

4. SOCIETIES may be referred to four several classes :—

1. FAMILIES,	3. NATIONS,
2. COMPANIES,	4. EMPIRES.

5. FAMILIES are united by *affection;* companies by the *desire of society;* NATIONS by the *desire of security;* and EMPIRES by *force.*

Obs. 1. *Men*, by their *confederacy* as well as by their *artifice*, are enabled to subdue every other species of animal, to subsist by their spoils, and to employ to their advantage the strength of other animals though superior to their own.

2. *Separate* societies are, for the most part, rivals or enemies.—Thus, Great Britain and France are reciprocally rivals in literature, science, and arms.

Questions for Examination.

1. Into what classes are animals distinguished? 2. What are the solitary animals? 3. What also the social? 4. To what classes may societies be referred? 5. How are these classes united; and with what advantages?

Section VII.

Of Population.

1. Men exist in greater numbers than any other species of the larger animals. In some cases, however, they are found to increase, in others to decrease, in their numbers.

Obs. The quick or slow increase of animals, in general, depends on the *physical laws* of propagation, on the *security*, and on the *means of subsistence* which the species enjoys.

2. The *laws of propagation* determine the numbers that may spring from any single pair, and the numbers of generations that may subsist together. And these laws, in every species of animals, are, in favourable circumstances, sufficient to the increase of the species.

2. Men, in every *secure* situation, people up to their resources; and the aid of government is

required, *not to improve* on the laws of propagation, but *to bestow security and plenty*.

Obs. Animals of *prey* have much difficulty in procuring their food; those which are preyed on are least secure.

3. The *security* and *subsistence* of men are most impaired by their own mutual hostilities and oppressions, of malice and of ambition.

Obs. The *laws of propagation*, as well as the means of subsistence, are supposed most favourable to population in the *warmer* climates. And to this we impute the populousness of nations in those climates, even under great defects of government

4. In taking a general survey of the earth, the surface of which contains 198,950,786 square miles, more than two-thirds of it are covered with water; and the seas and unknown parts are said to contain 159,966,217 square miles; therefore, the inhabited parts are equal to 36,990,569 square miles, of which

Europe contains	4,450,065	square miles.
Asia	10,768,823	
Africa	9,654,807	
America	14,116,874	
Total	38,990,569	

5. And the following has been given as an estimate of the population of the globe;—

Assia contains	500,000,000	souls.
Europe	150,000,000	
Africa	30,000,000	
America	20,000,000	
Australasia, Polynesia, and Isles in the Pacific Ocean	500,000	
Total	700,500,000	

6. Now, admitting the above calculations to be accurate, the population to every square mile will be:

1. To Europe 34 souls nearly
2. To Assia 46,
3. To Africa 3, and
4. To America there can only be 3 inhabitants to every 2 sqr. miles.

Questions for Examination.

1. Do men exist in greater numbers than any other species of the larger animals? And on what laws does the quick or slow increase of animals depend? 2. Of what use are governments to men in every secure situation? 3. How are the security and subsistence of men most impaired? 4. What is the number of square miles of the globe of the earth? and of these how many are inhabited in the several quarters? 5. How is the population of each quarter estimated? 6. And how many inhabitants to a square mile are there in each quarter?

Section VIII.

Varieties of Choice and Pursuit.

1. Men have not, like the other animals, a fixed and determined choice of external objects and pursuits; for these objects and pursuits to a being endowed with reason, must ever be the result of *education*, of *circumstances*, of *necessity*, and of *local attachments*.

2. Nations are frequently, by the difference of their manners and by their customs, mutual objects of wonder and censure, of contempt and aversion.

Illus. Thus, the peasant views the rites of a religion different from that in which he was educated, with astonishment as great as if he saw some flagrant breach of the moral duties, or some direct act of impiety to Heaven. And the ancient heathen and the modern savage teach us to do good to friends, but to be equally studious to injure our enemies. The milder precepts of Christianity, however, exhort us to unlimited forgiveness of injuries.

3. Even of two men placed in the same or like circumstances, *one acquiesces*, or *is pleased;* the *other complains.*

Illus. Thus, Oliver Goldsmith manifested a philosophic resignation to his fortune; Samuel Johnson had some daily lamentation: Robert Burns's mind was superior to despair; Chatterton yeilded to its gloomy influence, and died by his own hand.

4. Men differ in respect to the *means* which they employ for the attainment of the same, or of similar ends.

Illus. One man uses *force*, another *persuasion;* the former is naturally impetuous, and fancies all men may be driven; the latter is mild and calculating, and succeeds by the gentle method of leading. The one does not act according to the rules of common prudence; the other with much humility of conduct may yet preserve all the dignity of human nature.

Questions for Examination.

1. Of what are man's objects and pursuits the result? 2. Whence are Nations frequently the objects of wonder and censure to each other? 3. Do men in the same circumstances always acquiesce? 4. How do men differ in respect to the means which they employ to attain the same or similar ends?

SECTION IX.

Arts and Commerce.

1. The MATERIALS which men are concerned to provide may be classed under the following five general titles:---the means of *safety*, *subsistence*, *accommodation*, and *ornament*.

Obs. These considerations lead to the practice of many arts, which are more or less successful in proportion as they are multiplied, separated and complete: and they also suggest the advantages of property and wealth.

2. The consideration of SAFETY leads to the invention of *arms* and *places of retreat*.

Illus. 1. The first *weapons* appear to have been the club, a pole pointed at one end, the sling, and the bow. But to these succeeded in process of time the spear and the sword, joined to the buckler or shield. The invention of gunpowder led to the invention of fire-arms, cannon, musketry.

2. The desire of *retreat* has given rise to the art of fortification. And the art of war in every age must be accommodated to the species of arms, engines, and methods of fortification in use.

3. The ARTS which men practice for subsistence are

1. FISHING,	3. PASTURAGE, and
2. HUNTING,	4. AGRICULTURE.

4. NATIONS that know least of the means of SUBSISTENCE, not finding enough in the spontaneous growth of the earth, have recourse to HUNTING and FISHING. And in the result of these arts, the hunting-ground, the lake, the river, or the

bay, may be appropriated to the society or tribe; but the game is seldom appropriated to the individuals: it is the property of the tribe who feast on it in common.

5. NATIONS that have observed the method and the advantages of breeding herds, betake themselves to PASTURAGE.

Obs. They at first generally migrate or wander with their herds. The individual has, therefore, no immediate property in the land, though he boasts, as his own, the cattle he drives and tends. And in those countries in which there exists no property in the land, as in many parts of America and Asia, the soil is not cultivated, notwithstanding its acknowledged fertility and the genial influence of climate.

7. NATIONS that are acquainted with the use of *herbs*, *fruits*, and *grain* which do not grow spontaneously, or which do not grow in sufficient quantities to supply food for the whole community, betake themselves to AGRICULTURE.

Obs. 1. The CULTURE of the land, to a certain degree, may precede property, as it did among the ancient Germans; also among the nations of North America, and in some parts of Africa and Asia.

2. AGRICULTURE, where the object is the *temporary* produce of land, is compatible with migration; but in this case the subsistence is precarious, as the crops are liable to be seized or destroyed by other migratory tribes. Where the object is the improvement of the soil, and perpetual fertility, agriculture acquires settlement, and land becomes a property out of which the proprietor hopes to reap the reward of his labour by a harvest that shall secure himself and his family from want.

7. As the property of land excites to invention in agriculture, it likewise excites to invention in other arts. For they who have no land betake themselves to *manufacture*, that they may have wherewith to buy the produce of land. And by manufacture, men are furnished with the means of *accommodation* and *ornament*.

8. The means of ACCOMMODATION are *clothes*, *houses*, *furniture*, *utensils*, and *equipage*.

Obs. Men, in different ages, are unequally furnished with these articles; they even subsist without them; but in the ruder climates, under such inconveniences as diminish the number of the species and prevent their increase.

9. The means of *decoration* are such things as please the fancy without being useful. And in all ages men are fond of decoration; they even combine ornament with the means of subsistence and accommodation; but they may subsist and enjoy every conveniency, without regard to ornament.

Obs. Ornaments are principally made of rare materials; as *gems*, *precious metals*, &c.

10. RICHES consist in the abundance of things that conduce to *safety*, *subsistence*, *accommodation*, and *ornament*. Riches are the result of *arts* and *industry*.

Obs. 1. Whatever ingenuity men exert in the practice of arts, their success will depend upon a proper *distribution* of their employments, and on their making a separate business of *each*.

2. In making this division of labour, the parties trust that they may be able to exchange what they have to spare for what they want.

11. The progress of arts, as well as the casual distribution of commodities, depending on situation, climate, and soil, render COMMERCE expedient and even necessary.

Obs. COMMERCE, in its simplest form, consists of *barter,* without any standard of valuation, or medium of exchange. Each party gives what he has to spare of one kind for what he wants of another.

12. To extend trade, *money, communication,* and the interposition of *merchants* are required.

Obs. 1. The first *medium* of exchange, (that is to say, *money)* was generally some staple commodity; as, *corn, cattle,* &c. But these things being of uncertain value, of inconvenient bulk, perishing or expensive in the keeping, and not easily divided, without making an exchange of value, mankind adopted the *precious metals* as the medium of exchange; and for the greater convenience of trade, employed them in the form of *coins;* as the *Guinea,* the *Shilling,* &c.

2. The use of coin and actual payments in money not being absolutely necessary in every commercial transaction among merchants of known probity, as well as to avoid the cumbersomeness and inconvenience occurring in the transfer of large sums of the precious metals, the practice of *circulating bills* has been adopted; as, for example, *Bank Notes.* This practice founded in *credit,* tends also to extend that credit.

13. COMMERCE employs a number of separate *professions;* as, the MANUFACTURER, the FACTOR, the CARRIER, the MERCHANT, the RETAILER, &c.

14. The PRICE of commodities in trade is as their scarcity combined with their demand.

Illus. Articles, in the production of which labour, time, and skill, are required, continue to multiply, while the price is sufficient to maintain the labourer during the time he is employed, to reimburse his apprenticeship and other expences, and to furnish an adequate reward: when the price falls below this measure, the manufacture is discontinued until the scarcity brings up the price.

Questions for Examination.

1. To what titles do you refer the materials men are concerned to provide?

2. Illustrate to me to what the consideration of safety leads.

3. What are the arts which men practice for subsistence?

4. What nations betake themselves to hunting and fishing? How is their game appropriated?

5. What nations betake themselves to pasturage? And what is their chief property?

6. What nations become agricultural? What does the culture of the land precede? And with what is agriculture sometimes compatible?

7. How does property in land lead to invention in the arts?

8. Describe the means of accommodation; and what kinds of it have men in the savage and civilized states respectively?

9. What are the means of *decoration?* What are *ornaments?*

10. What are *riches?* and how acquired?

11. What is commerce? and how conducted?

12. What is *money?* What are the first media of exchange? What is the second medium?

13. What professions does commerce employ?

14. What are the rates of the price of commodities? and how are artizans reimbursed for their labour, time, and skill?

SECTION X.

Disparity of Rank.

1. Men are diversified, in respect to their PERSONAL QUALITIES and CONDITIONS.

Obs. The distinctions of *personal qualities* arise from unequal strength and capacity, unequal knowledge, resolution and courage, unlike dispositions of benevolence or malice.

2. These differences constitute either ***relations*** of ***dependence*** and ***power***; or ***comparative degrees*** of ***estimation***.

Illus. Thus, the strong, the knowing, the brave, are powerful; the weak, the ignorant, the fearful, are dependent. The benevolent are beloved; the malicious are detested. The knowing, the generous, and the brave, are esteemed; the ignorant, the ungenerous, and the cowardly, are contemned: and all the qualities of human nature being referred to arrangements or classes of excellence and defect, *one* man is held to be *more*, another to be *less worthy*.

3. Men differ in their predilection of *qualities* considered as the constituents of excellence.—They prefer qualities the most necessary in their own situations, and the most eminent in their own way.

Illus. 1. In dangerous situations, and in warlike ages, men chiefly admire *valour*, as was the case with the Spartans, &c.

2. In learned societies, they admire *knowledge* and *ingenuity*; as was the case at Athens, &c.

3. In trading nations *industry*, *punctuality*, and *fair dealing*, are in highest estimation; as is the case now in Great Britain, &c.

4. But there being some circumstances common in the situation and disposition of all mankind, such as, their being united in society, and concerned in what relates to their fellow creatures;—men universally admire qualities which constitute or procure the good of mankind; as, *wisdom, justice, courage,* and *temperance.*

5. *Such qualities* are generally comprehended under the title of VIRTUE; and *opposite* qualities, under that of VICE.

4. The *external* conditions of men are sometimes confounded with personal qualities, and appear to have the same effects.

Illus. The *rich* are powerful, the *poor* are dependent. Riches and birth, even equipage and dress, are admired. The reverse of these, poverty, obscurity, and mean attire, are looked upon, by the unphilosophic observer, with contempt or neglect.

Obs. Disparities are found in every state of society; they are greatest, however, where riches, power, and education, are most unequally distributed.

Questions for Examination.

1. How are men diversified in respect to their personal qualities and conditions?
2. What relations do these differences constitute?
3. Illustrate how men differ in their predilection of qualities considered as the constituents of excellence.
4. Also, how the external conditions of men are sometimes compounded with personal qualities.

SECTION XI.

Of Political Establishments.

1. Where men associate from affection and choice, and with little sense of private or of se-

parate interest, they have been known to subsist without rule or political establishment. Even where they associate from a sense of expediency or necessity, they follow, without rule, the suggestion of every particular occasion. But in maintaining an union which has arisen from *casual* coalitions, or *force*, societies have been obliged to adopt and to submit to GOVERNMENT.

Illus. 1. Where the coalition was *casual* or *forced*, individuals felt separate interests, and wished for rules to adjust their pretensions. Some suffered themselves to be governed, others pretended to government, on the footing of casual dependency or superiority.

2. The abuses of casual subordination have led men to think of POSITIVE *institutions*. And positive institutions have confirmed, altered, or restrained the powers which arise from casual subordination.

2. All POLITICAL INSTITUTIONS may be reduced to two general classes; the *simple* and the *mixed*.

Illus. 1. Under SIMPLE INSTITUTIONS, the *supreme power* is committed to a *single person*, or to a *single assembly of men*.

2. In *mixed institutions*, the *supreme authority* is exercised by a *plurality of collateral powers*.

3. SIMPLE INSTITUTIONS are *Democracy*, *Aristocracy*, *Monarchy*, and *Despotism*.

Illus. 1. DEMOCRACY is the supreme power of the collective body. This institution is calculated to correct, or to remove the effects of adventitious dependency and subordination, and to reconcile equality with order.

2. ARISTOCRACY is the supreme power of a particular rank or class of men. This class of men has, in some

cases, been *elective*; in others, *hereditary*. The institution itself, though calculated to confirm the superiority of one rank, and the dependence of the other, may, notwithstanding, preserve equality among the members of each class.

3. MONARCHY is the supreme power of a *single person*, who, placed at the head of many subordinate dignities, has an *authority defined by laws*. This institution is calculated to confirm adventitious dependency and subordination.

Obs. Extensive and perpetual military arrangements have led to monarchical subordination.

Illus. 4. DESPOTISM is the supreme power of a single person assumed and maintained by force, on the ruin of every other pretension to rank.

Obs. All Despotisms spring originally out of conquest or military usurpation.

4. MIXED INSTITUTIONS are, either *mixed Republics*, or *mixed Monarchies*.

Illus. 1. In MIXED REPUBLICS, the *supreme power* has been shared between the *collective body*, and a *Senate* or *Convention* of *nobles*.

2. In MIXED MONARCHIES the *supreme power* has been shared between a *king* and *nobles*, or between a *king*, *nobles*, and *people*; as is the case in Britain, &c.

Questions for Examination.

1. What is the origin of Government? and what have been the effects of casual coalitions on individuals, and on societies? 2. To what may all political institutions be reduced? 3. Define simple institutions: Domocracy, Monarchy, and Despotism. 4. Also mixed institutions; as mixed Republics, and mixed Monarchies.

Section XII.

Of Language and Literature.

1. Language, in the most general sense, comprehends all the external signs of *thought*, *sentiment*, or *will*.

Illus. 1. Signs are either *original* or *conventional.* Original *signs* are such as men are led by instinct to employ and to interpret: such are *tones* of the *voice*, *change of features*, and *gestures*. Conventional *signs* are such as men have agreed upon, or rendered customary; and consist of mute signs, speech, and written characters.

2. Where men are restrained from the use of speech, or are defective in the organs of hearing, or of pronunciation, they have recourse to *mute signs;* and thereby attain, in a considerable degree, the purposes of language. And different nations employ unequal measures of action, and of mute signs, together with *speech*.

2. Speech is universal to mankind, and peculiar to the human species. And every *separate* nation, or tribe, has had, for the most part, a separate language, or *different dialect*.

Illus. 1. The theory of speech, whether universal, or particular, is the *science* of grammar.

2. Written *characters* are the signs of words, or of articulate sounds, and these characters are either *verbal* or *alphabetical.*

3. Verbal characters are the signs of entire words. Alphabetical characters are the signs of elementary sounds or modulations; and the combination of these characters constitutes words.

3. Writing preserves the *memory* of past transactions, of observation, and experience.

And while it preserves literary productions, it tends also to improve and to extend the use of speech.

Obs. We refer *literary productions* to three principal titles---HISTORY, POETRY, and SCIENCE. The *first* and *third* treat of realities; the *second* extends to *invention*, or fiction; and men have excelled in *poetry*, while they were yet rude in *history* or *science*.

Note. We refer the student to the ELEMENTS of POLITE LITERATURE for such information as the development of this section naturally and scientifically involves. And in the "ELEMENTS OF SCIENCE AND ART," *Grammar, Rhetoric, Morals, Religion, Constitution and Government, Agriculture*, and, in short, the various useful and ornamental arts, are fully handled.

Questions for Examination.

1. What does language comprehend? and what are original and conventional signs?
2. What of the universality of speech; its theory; written and verbal characters?
3. What does writing preserve? And to what principal titles do we refer literary productions?

Note. In the chapter just ended we have developed the history of the *species*, man.—The history of man as an *individual* is treated in the "ELEMENTS OF POLITE LITERATURE," to which, therefore, we refer the student.

CHAPTER III.

NATURAL HISTORY.

Classification of Beasts.

1 *Introd.* The most celebrated naturalists have arranged beasts into thirteen distinct classes.

First, those of the *horse* kind; second, the *cow* kind; third, the *sheep* kind; fourth, the *deer* kind; fifth, the *hog* kind; sixth, the *cat* kind; seventh, the *dog* kind; eighth, the *weasel* kind; ninth, the *rabbit* kind; tenth, the *hedgehog* kind; eleventh, *amphibious* animals; twelfth, *apes* and *monkies*; and thirteenth, *winged quadrupeds.*

But besides these, the elephant, the rhinoceros, the hyppopotamus, the cameleopard, the camel, the bear, the badger, the tapir, the sloth, and some others, may each be considered as forming a distinct genus.

SECTION I.

Beasts of the First Class.

2. In this class we rank the horse as chief. The horse is an animal possessing beauty, strength, activity, and usefulness; and in whose welfare we are peculiarly interested. English horses are superior to those of other countries, for size and beauty; and are capable of performing what no others ever could perform. Thus, an ordinary racer can go at the rate of a mile in two minutes; and one horse has been known to draw the weight

of three tons. In their wild state, horses herd together, and in South America may be seen in droves of several hundreds.

The horse is distinguished from every other quadruped, by having the hoofs single, and his tail covered with long hair. The female is called a mare, and the young one a foal.

3. *The Ass is well known.* When very young, the ass is sprightly, and even tolerably handsome; but he soon loses these qualities, and becomes dull, stupid, and headstrong. But he is not equally stupid in all countries; for in Spain and some other countries, he is much more elegant and tractable; and if treated with care, there is no doubt that he might be rendered much more serviceable to us than he now is. Wild asses are fierce, swift, and formidable; and when pursued will defend themselves with courage.

The Mule.

4. A mule is a very hardy and useful animal, of a mixed breed, between the horse and the ass, both of which it somewhat resembles.

The Zebra.

5. A zebra is the most beautiful, though the wildest animal in nature; its head is large, its back straight, its legs finely placed, and its tail tufted at the end. Every part of the male zebra is adorned with stripes of brown and white, regularly disposed, and the only distinction between the beauty of the male and female is, that the stripes of the latter are alternately black and white. Zebras are *very scarce*, and are never seen in this country, except in collections of wild beasts.

Questions for Examination.

1. Into how many classes are beasts arranged? 2. Describe the horse. 3. Also the ass. 4—5. Likewise the mule and the zebra.

Section II.

Beasts of the Second Class.

1. *The ox.* Of all the various ruminating animals, (or such as chew the cud,) none deserve to be ranked before the ox, either for size or usefulness. The utility of oxen is worthy of our attention; for nearly the whole labour of agriculture may be performed by them; and, as food, the flesh of no animal is in greater esteem than that of the ox, and which we call beef. The male is called a bull, and the female a cow; the young of these service able animals is called a calf.

Variations of the Ox.

2. The urus, or wild bull, is chiefly found in Lithuania, and is prodigiously large.

3. The bison, which differs from the bull, by having a hump between the shoulders, and a long shaggy mane.

4. The zebu, or Barbary cow.

5. And the buffalo is an excessively strong and ferocious beast, and furnishes us with very superior leather, justly famed for its thickness, softness, and impenetrability.

Questions for Examination.

1. Describe the ox. 2. Describe among the varieties of the ox, the urus, the bison, the zebu, and the buffalo.

Section III.

Beasts of the Third Kind.

The Sheep.

1. The *sheep*, in its present domestic state, is, of all animals, the most harmless and inoffensive; and is too well known to require a detail of its habits. The male is called a ram; the female, an ewe; and the young one has the name of lamb.

2. There are various breeds of sheep, and great pains are taken by agriculturists to improve the quality of the wool, by mixing them. The Spanish or Merino breed is much celebrated, and from their fleeces the finest cloth is made. In Persia, Egypt, and Tartary, there are sheep, called broad-tailed sheep, remarkable for a large and heavy tail, frequently weighing from twenty to thirty pounds.

The Wild Sheep, or Moufflon.

3. The moufflon may be so called, as it bears all the marks of being of the primitive race. They range wild in the deserts of Tartary, and the uncultivated parts of Greece, Sardinia, and Corsica.

The Goat.

4. Goats approach more nearly to the character

of sheep than any other animals; but they are possessed of a greater share of instinct, and are stronger, swifter, and much more courageous.—The goat is lively and playful, and delights in climbing the steepest mountains, for which nature has peculiarly fitted him, by forming the hoof in such a manner, that it can walk as securely on the ridge of a house as on level ground.

5. Among the various kinds of goats we may reckon,

1. The Angora goat, which is beautifully white; the Assyrian goat, distinguished by its broad hanging ears; the little goat of Africa, not larger than a kid; the blue goat, found at the Cape of Good Hope; the Juda goat, nearly resembling ours, which is a native of the coast of Africa.

2. The ibex, or wild goat, known by its long horns; and the chamois, admired for its elegance and vivacity.

3. Such as rank between the goat and the deer, and which properly come under the appellation of gazelles, but are more commonly known by the name of antelopes. They are handsomely formed, and possess extraordinary swiftness.

Questions for Examination.

1. Describe the sheep, and mention its uses to man. 2. What various breeds of sheep are there? 3. Describe the wild sheep. 4. Describe the goat. 5. What various kinds of goats are there?—Among these describe the *Angora,* the ibex, and the antelope.

Section IV.

Beasts of the Fourth Kind.

1. These belong to the deer tribe, and are distinguished by their large branching horns, they shed annually, and are renewed; their skins, when

young, are remarkable for their softness; they are extremely active, and shy, and inhabit woods and sequestered situations.

2. *The Stag.*

Nature seems to have designed this péaceable animal as an ornament of the forest; for the lightness of his motions, the easy elegance of his form, the beauty of his branching horns, his strength and swiftness, are all calculated to excite our attention. His usual colour is a reddish brown, and from his horns smaller ones sprout out, which are called antlers; one of which generally makes its appearance every year; so that we have only to count the number of antlers to know the stag's age.

3. *The Fallow-Deer, the Roe-Buck, and the Axis.*

The male of the fallow-deer is called a buck, the female a doe, and the young one a fawn. On the continent they are to be met with in a wild state; but in this country they are only seen in parks. Their flesh is called venison, and is considered by epicures a delicious treat.

4. The roe-buck is much smaller than the fallow-deer, and its habits are different. Not associating like others of the deer kind, in herds, it exhibits an example of constancy, and resides continually with its favourite female and young ones.

The Elk and Rein-Deer.

5. The elk is the largest kind of deer, frequently the size

of a horse, and inhabits the forests of North America and Asia; there is no animal in the world more truly serviceable than the rein-deer is to the Laplander. Over regions of ice and snow, yoked to a sledge, this creature conveys the heaviest load, and his astonishing speed enables him to travel nearly a hundred miles in one day. The female supplies the Laplander with milk, which produces him butter and cheese; and the flesh of these animals, when killed, provides him with meat.

Questions for Examination.

1. To what tribe do the beasts of the fourth class belong? 2. Describe the stag, and mention its peculiarities. 3. Also the fallow-deer. 4. Likewise the roe-buck. 5. Also the elk and rein-deer.

Section V.

Beasts of the Fifth Class.

1. In this class, which includes all animals of the hog kind, we will first describe the wild boar.

The wild boar is, in fact, the hog in a wild state; and the difference observable in them arises from the long domestication of the same hog. The wild boar has the head and muzzle larger and stronger than the hog, the tusks stronger, and the hair, called bristles, always black; he is very ferocious and unmanageable, and will attack dogs, horses, and even men.

2. *The Tame Hog.*

Domestic hogs are the most inactive and brutal animals in nature, and devour the filthiest food with voracity. They frequently eat till they can

stand no longer, and when put up to fatten, will remain whole weeks in the same position.—Though their flesh is eaten by us, the Jews and Turks consider it impure.

Among the other animals of this class, we may specify:—

3. The *Peccary*, a native of South America, which is smaller than the common hog; the *Capibaru*, or, as some have termed it, the water-hog, from its frequenting the borders of lakes and rivers; and the *Babyroussa*, which, instead of bristles, has fine hair, and four long crooked tusks.

Questions for Examination.

1. Among beasts of the fifth class, describe the wild boar. 2. Also the tame hog. 3. Likewise the peccary, the capibara, and the babyroussa.

Section VI.

Beasts of the Sixth Class.

1. *The Cat.*

Of all animals, when young, none are more amusing or playful than the cat; but as it increases in age, it is found artful and insinuating, watching the most favorable opportunities to seize its prey, or purloin food, with which it runs off and remains at a distance, till its offence may be forgotten.

Cats are active, cleanly, and delicate; their skin is soft, and their fur is naturally sleek and glossy. With all their

want of attachment, which seems to be natural to the species, yet we frequently find them pleasant companions, and they are of the greatest service to us in destroying mice and rats.

2. *The Wild Cat.*

Wild cats are found in every quarter of the world; they are larger than the domestic ones, and much more formidable; their colour is a yellowish white, streaked with black and grey; the legs are invariably black, and the tail is alternately black and white.

3. *The Lion.*

The Lion is ranked in this class; on account of his having sharp and formidable claws, which he can sheathe and unsheathe at pleasure, and from deriving his subsistence from the prey of other animals.

His figure is noble and dignified, and his voice terrible. The face of the lion seems to indicate majesty, to which his large mane materially contributes; he is styled the king of beasts, for no animal can conquer him. Although so amazingly powerful, the lion is too generous in his nature to torture those in his power unnecessarily, and he has been frequently known to protect weaker animals from the fury of such as have pursued them. The female is called a lioness, and is distinguished from the male by being *smaller and having no mane.*

4. *The Tiger.*

The tiger, one of the fiercest, and at the same time one of the most beautiful of all quadrapeds, is about the size of the lion, and is remarkable

for the smoothness of its hair, which is of a yellowish brown, and for jet black stripes with which it is marked. It is a native of various parts both of Asia and Africa.

The tiger is fierce without provocation, and in attacking a flock, or herd, it gives no quarter, and will wantonly kill more than it can devour. The skins of these animals are used as hammer-cloths for carriages, &c. and are considered more as objects of curiosity than real use.

6. *The Panther, Ounce, the Hunting Leopard, and the Lynx,*

In their habits resemble the tiger, being all of the cat kind.

The panther has the upper part of the body covered with spots, and the lower part striped.

The ounce, and hunting leopard, are trained for the chase in India and Persia, and their mode of seizing the antelope or other animals, is by creeping along unperceived, till they approach near enough to dart upon their prey. Their skins are all valuable, and are converted into excellent furs.

The skin of the leopard is more beautiful than either of the others, but in its nature this animal is equally cruel and ferocious.

The skin of the lynx is spotted, but its tail is much shorter than that of the leopard. Its ears are also considerably longer, and tipped at the points with a black tuft of hair. It is very fond of climbing the highest trees, where it catches squirrels, ermines, &c., and will kill beasts much larger than itself. The Caracal and Serval bear a resemblance to the Lynx, but are rather smaller.

Questions for Examination.

1. Among beasts of the sixth class describe the cat.

2, 4, 5, Also the wild cat, the lion, and the tyger.

6. Likewise the panther, the ounce, the hunting leopard, and the lynx.

SECTION VII.

Beasts of the Seventh Class.

1. *The Dog.*

The dog is the most intelligent of all quadrupeds, and on no one can we depend for equal fidelity and attachment.

Though there are many kinds of dogs, they still retain such a similarity, that it is perfectly easy to distinguish them from any other species. The principal are the bull-dog, the mastiff, the pointer, the greyhound, the spaniel, the hound, the shepherd's dog, the lap-dog, and the terrier; but there are a variety of others, which may be considered mongrels.

2. *The Wolf.*

The wolf, in appearance, very much resembles the dog, but in disposition no two animals can be more dissimilar, nor can any have a more decided antipathy to each other. The wolf is very ravenous and insatiable. He will attack not only beasts, but men, when pressed with hunger. Wolves sometimes go together in numbers to attack other beasts, and destroy whole flocks and herds.

3. *The Fox.*

The artful disposition of the fox is well known, and he finds it a much easier method to provide himself with food by stratagem, than by encountering danger. He always makes choice of his abode near villages, where he can readily visit the farm-yards, and feast on poultry. The fox is fond of grapes, and honey, but less delicate food will serve him, when dainties are not to be procured.

4. *The Jackall.*

The jackall very much resembles both the fox and wolf in make; its colour is yellow, and on that account it has sometimes been called the golden wolf. To the savage ferocity of the wolf, the jackall adds the familiarity of the dog, and seems less afraid than any other animal.

5. *The Hyæna.*

The hyæna is a most furious and dangerous beast, and it is impossible to tame it, however young it may be taken. It is something like the wolf, but more formidable and courageous; and will resist the attacks of the tiger with success, and defend itself against the lion. It is a native of the warmest parts of Asia and Africa. It has longer legs than the wolf, the body thicker, the hair of a yellowish brown, the ears long and naked, and the muzzle flat.

Questions for Examination.

1. Describe the dog and relate its properties. 2—3. Also the wolf and the fox. 4—5. Likewise the jackall and the hyæna.

Section VIII.

Beasts of the Eighth Class.

1. *The Weasel.*

Weasels are known by the length and slenderness of their bodies. They are, in general, cruel, voracious, and cowardly. The weasel is small, being not more than seven inches long, and one inch and a half in height. It destroys young poultry, sucks eggs, and pursues rats and mice into their holes, where it soon kills them.

2. *The Ermine*

Very much resembles the weasel, but it is longer; the colour of the body is a light brown, but in the most northern parts of Europe it becomes perfectly white at the approach of winter, at which time its fur is deemed the most valuable of any animal.

3. The other animals constituting this class are, the erret, the pole-cat, the martin, the sable, the ichneumon, the squash, the skink, the zouille, the genette, the civet, the glutton, and the suricate. The martin and sable have fine skins; on account of which they are killed by the hunters of Siberia, and other cold countries. The ichneumon is remarkable for its courage and fierceness, and is of great service to the inhabitants of Egypt, by destroying serpents, and other noxious reptiles. The civet produces a strong perfume, known by the name of the animal, which is highly valued; and the glutton is so called from its voracious appetite.

Questions for Examination.

1. Among beasts of the eighth class describe the weasel. 2. Also the ermine. 3. Likewise, the ferret, the pole-cat, martin, sable, &c.

SECTION IX.

Beasts of the Ninth Class

Are those of the rabbit and hare kind.

1. *The Hare.*

The common hare, which is well known in this country, and is to be found in Europe, Asia, and

America, is distinguished by its long ears, short tail, and large prominent eyes, placed so far backward in the head, that it can see behind it as it runs: there is no animal more timid or inoffensive than the hare, yet no one has more persecutors. Dogs, cats, and the weasel tribe, continually annoy it; but man destroys more than all its other foes. The flesh of the hare is much esteemed by us, though the ancient Britons abhorred it.

2. *The Wild Rabbit.*

The wild rabbit greatly resembles the hare, but its ears and hind legs are shorter. The colour of the wild rabbit is a dusky brown above, and whitish on the under parts. The domestic rabbit is of various colours, and is larger than the wild one. The fur of rabbits and hares is a principal substance employed in making hats, and their flesh is considered very wholesome food; wild rabbits are however to be preferred to tame ones.

The marmot, the agouti, the paca, and the Guinea pig, are also of this tribe.

3. *The Marmot.*

The marmot is a native of the Alps, and when taken young, may be easily tamed, and taught a variety of agreeable tricks. They are very inoffensive, and in winter form curious retreats in the side of a mountain, where they apparently exist without food.

4. *The Agouti.*

The agouti differs from a rabbit, by having hair instead of fur, and is a voracious eater.

5. *The Paca.*

The paca is distinguished from the agouti, by its skin being very prettily spotted.

6. *The Guinea Pig.*

The guinea pig is the most timid and helpless of all animals; and the male and female never sleep at one time, but while one enjoys repose, the other is constantly on the watch.

In this class also we comprehend rats, though their habits and dispositions do not correspond with those of the rabit kind, being voracious and mischievous.

7. *The Rat.*

There are three kinds of rats: the brown rat, (which is the largest and strongest), the black rat, and the black water-rat. The mouse and the mole are likewise included in the same class.

8. *The Squirrel.*

The squirrel is smaller than the rabbit, and has a beautiful bushy tail, which it can spread so as to cover the whole body. Its colour is a reddish brown, and the ears are ornamented with long tufts of hair. It is generally seen leaping from one branch of a tree to another, or sitting on its hind legs, and using its fore paws in conveying nuts or acorns to its mouth.

9. *The Flying Squirrel.*

The flying squirrel is much less than the common squirrel; and from the peculiar formation of its skin, which spreads out between the hind legs, it is capable of taking surprising leaps, so as to resemble the act of flying.

Questions for Examination.

1. Describe the hare. 2. Also the wild rabbit. 3—4.

Also the marmot, and agouti. 5—6. Likewise the paca, and guinea pig. 7. Also the rat. 8—9. In like manner the squirrel, and flying squirrel, and their habits.

SECTION X.

Beasts of the Tenth Class.

The animals composing this class are distinguished by having in place of hair, sharp prickles, which they use for their defence.

1. *The Hedge Hog.*

This animal is about six or seven inches long, and is covered with prickles on the head, back, and sides; but the nose, belly, and breast are clothed with fine soft hair. As soon as the hedge-hog perceives an enemy, it rolls itself up like a ball, presenting a surface of sharp points, which is so annoying to any animal that attacks it, that it soon declines the combat.

2. *The Tanrec and Tendrac.*

These animals are less than the hedge-hog, and have not the power of rolling themselves like him; nor are they so well defended with sharp prickles.

3. *The Porcupine.*

The quills of the porcupine render it extremely formidable; but it is not true, that it can discharge these quills and inflict wounds at a distance, as some have asserted; the quills are of great use in defending the porcupine from the attacks of other animals, particularly serpents, to whom it has the most decided enmity; and these creatures never

meet without a mortal engagement. The coando and weson also have quills, but much shorter than those of the porcupine.

4. *The Pangolin and Armadillo.*

The *pangolin* and *armadillo* are also of this class; for nature having given them a coat with hard scales, which, like the prickles of the hedge-hog, serve for their defence; and they have the power of rolling themselves up in the same manner. They are naturally inoffensive, and subsist on vegetables.

Questions for Examination.

1. Of the animals distinguishing the fourth class, describe the hedge-hog. 2. The tanrec and tendrac. 3. The porcupine. 4. The pangolin and armadillo.

Section XI.

Beasts of the Eleventh Class.

These are amphibious animals, and exist either in water or on land.

1. *The Otter.*

The otter is about two feet long from the tip of the nose to its tail, the head and nose broad and flat; it has a short neck, long body, and small eyes. The legs are very short, and each foot is furnished with strong broad webs, like those of a water-fowl. It is very expert in catching fish, on which it subsists.

2. *The Beaver.*

A beaver has a broad flat tail, covered with

scales, which serves as a rudder, to direct its motions in the water. It has membranes between the toes on the hind feet only; the fore feet supply the place of hands, like those of the squirrel; and it is about two feet long, and a foot high.

In the summer the beavers assemble in great numbers, and construct large habitations, divided into small apartments, on the sides of rivers, which they do with surprising facility. With their teeth they cut large pieces of wood, and fix them in the ground, at a little distance from each other, placing smaller twigs between them; they then fill up the cavities with clay, and cement the whole together by mixing and moistening it with water, which they perform with their tails.

3. *The Seal.*

3. The seal resembles a quadruped in some respects, but is also like a fish. It has a round head, broad nose, and large sparkling eyes. From its body, which is covered with short shining hair, to its tail, it gradually grows more taper, like a fish, and its claws resemble fins. Seals are caught for the use of their skins, and the oil which their fat yields. Besides the common seal there are

4. The ursine seal, found at Kamtschatka; the sea lion, so called from having a mane; the morse, distinguished from the rest by having two long tusks; and the manati, which has a fish's tail, and is quite destitute even of the vestiges of those bones which form the legs and feet of others of its kind.

5. *The Platypus.*

5. The duck-billed platypus is in some respects a little like a small otter, and from the broadness of its snout, which resembles the bill of a duck, it takes its name. Its feet are webbed and the legs very short. Its whole length does not exceed thirteen inches.

Questions for Examination.

1. Among the amphibious animals of the eleventh class describe the otter. 2. Describe the beaver. 3. Likewise the seal. 4, 5, The ursine seal and the platypus.

Section XII.

Beasts of the Twelfth Class.

These are animals of the monkey kind.

1. *The Ourang Outang.*

The ourang outang, or wild man of the woods, is of various sizes, from three to seven feet high. Its stature is, however, generally less than that of a man, but its strength is much greater. It is said they are so powerful in some of the tropical climates, that it would take ten men to secure one of them; and they will attack the largest elephants with clubs, and compel them to leave that part of the forest which they claim as their own.

2. *Apes.*

There are several kinds of apes and baboons: as the common ape; the gibbon, or long armed ape; and the cynocephalus; neither of which have any tails; and the baboon, the mandril, and wanderow, which have very short tails.

3. *Monkeys.*

Monkeys have long tails, and some make use of them to coil round any object, so as to support themselves in otherwise perilous situations. They are a most active and mischievous race, and seem to be but of little use, except in some countries where they are eaten by the natives, and

said to be very palatable. An Englishman, however, would find it very repugnant to his feelings to partake of such food.

Questions for Examination.

Of the beasts of the 12th class describe, first, the ourang outang; 2, Apes; and 3, Monkeys.

Section XIII.

Beasts of the Thirteenth Class.

1. These are winged quadrupeds; but the structure of their bodies place them in this rank, though the property they possess of extending a thin membrane (mantle or skin) over their whole body, enables them to fly aloft in air like birds.

2. *Bats.*

There are many varieties of this species; but the bat most common in England is about the size of a mouse; and independant of its wings, very much resembles that little animal.

In Madagascar there is a very large kind of bat, called the rousette, which, when the wings are extended, is four feet broad and a foot long. Its colour and the shape of its head are like a fox, and on that account it has sometimes been called the flying fox. They are hideous looking creatures, and do an incredible deal of mischief.

Questions for Examination.

1. What beasts compose the thirteenth class?
2. What is the description of the bat? and what of the Madagascar bat?

Section XIV.

Separate and distinct animals, each of which

forms a class to itself; as the Elephant, the Rhinocerous, the Hippopotamus, and the Tapir, &c.

1. *The Elephant.*

The elephant surpasses all other terrestrial animals in size, and in sagacity he is inferior only to man. Like the dog, he is susceptible of gratitude, and capable of attachment; he possesses the most astonishing strength, yet, when tame, he submits to the will of his master, and is a pattern of fidelity and docility. Elephants have been seen fifteen feet high; their colour is an ash grey; and they have a trunk which they can shorten or lengthen, and with which they are able to pick up money from the ground, untie knots, and perform many things equally curious to the beholder. In his appearance the elephant is clumsy and unsightly; but his instinct is so superior, that he seems to think, reflect, and deliberate. His tusks furnish us with that elegant and useful substance called ivory.

2. *The Rhinocerous.*

The rhinocerous is, next to the elephant, the most powerful of all beasts. He is twelve feet long, and from six to seven feet high. His limbs are covered with an impenetrable skin, that defies the hunter's dart, or the attacks of the lion or tiger. This skin is converted into the hardest kind of leather.

3. *The Hyppopotamus.*

The hyppopotamus is equally large and formidable as the rhinocerous. They reside chiefly at the bottom of

lakes and rivers, and depend on fish for subsistence, which they catch with great celerity. When they are compelled to seek their food on land, their depredations are truly alarming to the helpless Africans, who dare not resist them for fear of their resentment.

4. *The Tapir.*

The tapir may be considered the hyppopotamus of America, but it is much smaller and less to be dreaded than its African brother.

5. *The Camel.*

The camel is so useful an animal to the Arabians that it is considered sacred by them; and without its assistance these people could neither traffic, travel, nor subsist. In Turkey, Persia, Arabia, and Egypt. commerce is entirely carried on by means of camels, no carriage being so speedy and reasonable in these climates. They are admirably adapted for these climates, by being capable of enduring thirst, and from being able to perform immense journeys over the most unfertile and sandy desert.

6. *The Dromedary.*

The dromedary has but one hump on the back, while the camel has two; in size and strength it is not equal to the latter. They both furnish their owners with milk, and their hair, which they shed annually, provides them with clothing.

7. *The Cameleopard.*

The cameleopard has some resemblance both to the camel and the deer, though it neither possesses the strength of the one nor the swiftness of the other. Its height, when full grown, from the fore foot to the top of

the head, is about seventeen feet, and its skin is beautifully spotted with brown on a white ground.

8. *The Bear.*

There are three sorts of bears, the brown bear, the black bear, and the great Greenland or white bear. The brown bear is a savage animal, inhabiting the most dangerous precipices and uninhabited mountains. In Canada, the black bears are very common, and their flesh is so much esteemed, that their hams are imported to England. But the white bear of Greenland, is by far the largest, and yet the most timorous. The affection of these animals for their young has been noticed as truly wonderful.

9. *The Badger.*

The badger is a solitary, stupid animal, that seldom ventures far from its hole. It sleeps the greatest part of its time, but when roused by the pursuit of dogs, makes a very vigorous resistance.

10. *The Ant-eater.*

The ant-eater, as its name implies, subsists entirely on ants and insects, which it allures by laying out its tongue on an ant-hill, till the insects gets upon it, when it swallows them; and this it repeats till it has procured a sufficient quantity to satisfy its hunger. The legs of the ant-eater are very short, and the nose, or snout, is extremely long and taper. There are three varieties of this animal, differing much in size, the largest being four feet long, the next eighteen inches, and the smallest only seven.

11. *The Sloth.*

The sloth is the most inactive animal known, and lives entirely upon vegetable food. When it is impelled, by hunger, to seek subsistence, it crawls to some tree, which it strips of its bark and leaves, and being unable to descend, drops on the ground from the branches. The

strength of its feet is so great, that it is scarcely possible to free any thing from its claws.

Questions for Examination.

1. Describe the elephant.
2. Also the rhinocerous.
3. Likewise the hyppopotamus.
4. Also the tapir.
5, 6. Likewise the camel and dromedary.
7. Describe the cameleopard.
8, 9. Also the bear and badger.
10, 11. Likewise the ant-eater and sloth.

SECTION XV.

Introduction.

Birds.

The Ostrich.

Previous to arranging them in classes, we will mention the ostrich, which is the largest, and bears the nearest affinity of any to quadrupeds. It is seven feet high, from the top of the head to the ground; and, at a distance, might be mistaken for a camel. It inhabits the sandy deserts of Arabia, and there is no place, however barren, that is not capable of supplying it with provision, its powers of digestion enabling it to devour leather, stones, iron, or any other hard substance.

We shall follow the plan of Linnæus, who divides birds into six classes; namely, the rapacious kind, the pie kind, the poultry kind, the sparrow kind, the crane kind, and the duck kind, or water-fowl.

2. *Rapacious Class.*

By the rapacious kind is meant those which eat flesh, and subsist by rapine. They consist of eagles, vultures, falcons, kites, buzzards, hawks, and owls; they are distinguished by a strong crooked beak, short legs, and sharp crooked talons.

3. *The Eagle.*

Of this class the eagle is the largest and most noble. It is about three feet in length, and the extent of its wings is upwards of seven feet. This bird may justly be stiled the king of the feathered race; and, like the lion among quadrupeds, is remarkable for courage and magnanimity.

4. *The Vulture.*

The Egyptian or aqualine vulture is a large bird of prey, having a naked head and neck, and a black hooked beak. In its appearance it is disgusting, but is nevertheless of the greatest service to mankind, in those hot countries where it resides, by devouring the remains of animal substances, which would otherwise be left to putrify. These vultures were held in such veneration by the ancient Egyptians, that any persons who destroyed them were punished with death.

5. *The Pie Class.*

The pie kind have the bill resembling a wedge; their body is slender, and their voices hoarse—they may be known also by being noisy

and chattering. In this class may be reckoned the raven, the rook, the crow, the magpie, the parrot, the cockatoo, the jay, the cuckoo, the woodpecker, &c.

6. *The Raven.*

The raven is the largest bird of this kind; its plumage is of a bluish black colour, and it is to be found in most European countries, and also in North America.

Ravens are very serviceable in destroying mice, rats, and other vermin, and are easily domesticated. The ancients esteemed these birds, from a notion that, by the various tones or modulations of their voice, future events might be foretold.

7. *Poultry Class.*

Birds of the poultry kind are the peacock, the turkey, the domestic cock, the pheasant, the guinea-fowl, the bustard, the partridge, the quail, the goose, &c.

They are furnished with short strong bills and short wings, with which they are unable to fly far. Their food consists chiefly of grain; and except the peacock, they furnish us with palatable and wholesome food.

The Peacock has a most beautiful plumage, and when its tail is expanded, no other bird can vie with it for beauty. Its voice, however, is a horrid scream, and it is remarkable for gluttony.

8. *Sparrow Class.*

The class comprising the sparrow kind are, the thrush, the blackbird, the fieldfare, the star-

ling, the nightingale, the mockbird, the red-breast, the lark, the wren, the canary bird, the goldfinch, the bullfinch, the sparrow, the swallow, the martin, and the humming bird.

Some of them delight us with the beauty of their plumage, others with the melody of their notes, but all contribute to enliven the rural scene and exhilarate the mind. They live either on insects, grain, or fruit; so that though we may be offended with their intrusive visits in our fields and gardens, we are compensated by the use they are of in destroying the various kinds of vermin that infest them.

Example. Thus, the nightingale which in solitude delights us with its melody, is a small migratory bird, of a rusty brown colour, generally arriving in this country in the month of April, and leaving it in September, retiring into a warmer climate during winter. The song of the nightingale is peculiarly mellow and plaintive, and the compass of its voice is greater than that of any other bird. His usual resort is the side of a hill, where perched upon a tree or shrub, he interrupts his warblings by making short pauses, as if listening to the echo of his own notes.

9. *Crane Class.*

The class of the crane tribe includes the crane, the stork, the heron, the bittern, the spoonbill, the flamingo, the aoosetta, the woodcock, the water-hen, and the coot.

These birds are distinguished by the length of their legs, and their frequenting rivers and marshy places. Their necks and bills are also much longer than those of other birds, which are adapted to their mode of subsistence, being calculated to fetch up their food from the bottom of shallow waters. They are distinguished from water-fowl, from their not being able to swim.

10. *Duck Class.*

The duck kind or water fowls naturally come under three divisions, viz.—those of the duck kind, with flat broad bills and webbed feet; those of the penguin kind, with round bills and short wings; and those of the gull kind, with long legs and round bills, and which fly along the surface of the water to seize their prey.

The chief of these are, 1. the swan, the wild goose, the common goose, the wild and tame duck, and the king fisher. 2. The penguin and the puffin. 3. The pelican, the albatross, the cormorant, the gannet and the gull.

11. *The Swan.*

The tame swan is the largest of all British birds, and is distinguished from the wild swan by being larger, and by the base of the bill being black instead of yellow. They form their nests of grass, and generally among reeds near the water. Their eggs are large and white, and six or eight in number. These birds are mostly esteemed for their beauty and stately appearance. Though formerly they were considered a delicacy, and served up at almost every great feast, at present, the cygnets or young swans, only are eaten, and great numbers are annually fattened in the county of Norfolk.

12. *The Penguin.*

A penguin is an aquatic bird, with a strait and narrow bill, and legs situated so far back that it walks in an upright position; its wings are small and not calculated for flight, being covered over with a broad and strong membrane.

These birds are found in the different islands of the south sea; and they are so fearless of the approach of mankind, that there is no dificulty of knocking them down

with sticks. Their flesh is eaten by seamen when they are short of provisions, and is sometimes salted like beef.

13. *The Pelican.*

The are several species of pelicans, but the most remarkable is the great white pelican, which is furnished with a bag attached to the lower part of his bill, large enough to contain a great number of fish. On these the pelican feeds, and by means of this bag it is enabled to convey its prey as food for its offspring.

Questions for Examination.

1. Describe the ostrich.
2. Describe the rapacious class of birds.
3, 4. Describe the eagle and vulture.
5, 6. Describe the pie class of birds, and the raven.
7. Also the birds of the poultry class.
8. What are those of the sparrow kind?
9. What birds does the crane tribe include?
10. What are the characteristics of the duck tribe?
11. 12, 13. Describe the swan; the penguin, and the pelican.

Section XVI.

Fishes.

Introd. In treating of fishes, our observations and descriptions will be general, containing such information of their nature, habits and properties, as are most deserving of the pupil's attention.

1. Fishes are divided into the cetaceous or whale kind; the cartilaginous, or gristly kind; the spinous, or those fishes whose bones resemble sharp thorns; and the testaceous, or such as are covered with shells instead of scales.

2. Most fishes have nearly the same external form, sharp at the ends, swelling in the middle, and their bodies

provided with fins, by which they are enabled to swim with great celerity and ease. Every part of the body seems exerted to assist their motion in the water; the fins, the tail, and the flexibility of the body are alike employed, and it is to the union of these that they owe their great velocity.

3. As respects their general habits we may observe, that as neither the sea nor fresh water produces an abundance of vegetables, like the earth, the inhabitants of the watery element could not be supported, did they not continually devour one another. Their astonishing fecundity, however, amply provides them with the means of subsistence; for it is no more wonderful than true, that the flounder produces above a million, and the mackrel above five hundred thousand of its species at one time. Thus, two wise purposes are answered by this amazing increase; there are enough produced to preserve the species in the midst of its numberless enemies, and to furnish the rest with a sustenance adapted to their nature.

4. *The Cetaceous Class, or Whale Kind.*

The largest animal in the whole creation is the Greenland great whale. It usually measures upwards of sixty feet in length; its fins are from five to eight feet long, and its tail is twenty four feet broad. The tongue alone produces several hogsheads of blubber. The substance called whalebone is taken from the upper jaw of this stupendous animal, and is very different from its real bones, which are hard, like those of large quadrupeds, and full of marrow.

Every whale is computed to yield, on an average, from sixty to an hundred barrels of oil, of the value of about four pounds sterling per barrel, which, with the whalebone, is sufficient to prove how valuable this fish is to us in a commercial point of view. The method of killing whales

is very interesting, but too long to give a particular account of here.

5. *The Cartilaginous Class.*

Fishes of the cartilaginous kinds have bones always soft and yielding; and age, which hardens the bones of other animals, rather contributes still more to soften theirs.

These fishes are divided into four kinds; 1st. Those of the shark kind; namely, the great white shark, the balance-fish, the hound-fish, the monk-fish, the dog-fish, the basking-shark, the zygœna, the cat-fish, the blue-shark, and the sea fox.

2ndly, Those called flat fish. In this tribe may be placed the torpedo, the skate, the ray, the thorn-back, and the fire-flare.

3rdly, The slender snake shaped kind, such as the lamprey, the pride, and the pipe-fish; and

4thly, Those of different figures and natures that do not rank in the former divisions; namely, the sturgeon, the sun-fish, the tetrodon, the lump-fish, the sea-snail, the chimera, and the fishing-frog.

6. The third class are the spinous or bony kind.

These are distinguished from the rest by having a complete bony covering to their gills; by their being furnished with no other method of breathing but gills only; and by their bones being sharp and thorny. There are already known more than four hundred species of the spinous kind; so that the number of the two former are trifling in comparison to them.

7. *The fourth Class comprehends all such as have shells.*

In this division must be reckoned all such as are called crustaceous and testaceous animals; both unlike fishes in

appearance, for, from having shells on the outside, instead of bones in the inside, they seem to invert the order of nature.

8. Crustaceous Fish.

Those called crustaceous, are such as have a shell not quite impenetrable, but rather resembling a firm crust, and in some measure capable of yielding; there are two kinds. [The chief of one kind is the lobster, and with it may be ranked the crab, the prawn, the cray-fish, and the shrimp. The chief of the other is the tortoise, and its varieties, such as the turtle, &c.

9. Testaceous fish are such as have hard shells, of a stony substance, which, like that of the oyster, muscle, &c. serves to protect the fish it incloses. They are divided into three kinds, namely, univalve, or turbinated, consisting of one piece, like the house of a snail; the bivalve, consisting of two pieces united by a hinge, like an oyster; and the multivalve, consisting of more than two pieces, as the acorn-shell, which is formed of no less than twelve pieces. All these kinds, in numberless varieties, are found in the sea at different depths, and are valuable in proportion to their scarceness and beauty.

Questions for Examination.

1. Into what classes are fishes divided ?
2. What are the external characteristics of fishes ?
3. What is recorded of their fecundity.
4. Describe the cetaceous, or whale kind.
5. Also the cartilaginous class.
6. Describe now the spinous, or bony kind.
7. Also those which have shells : as
8. The crustaceous, and
9. The testaceous kinds.

Section XVII.

Reptiles.

Introd. How disgusting soever reptiles may appear both in their figure and properties, since they form a part of animated nature, they claim our attention in this view of Natural History.

1. The reptile race may be divided into four tribes, and may be classed under the frog, toad, lizard, and serpent kind: the two former are so well known, that we shall not describe their formation, but we shall merely observe, that a very great error generally exists with respect to the toad. It has been thought that these reptiles contain poison, and that they have the power of ejecting it, but the fact is that they are torpid, harmless animals, passing the greatest part of winter in sleep; and no more deserve inhuman treatment than those animals which we consider useful and handsome.

2. *The Lizard Tribe.*

The Crocodile.

The crocodile, is not only the most terrible and mischievous of the lizard tribe, but also of all those animals which nature has produced. It is a native both of Africa and America, and frequently grows to the size of twenty feet in length, and five feet in circumference. Its skin is defended by a suit of armour, composed of large scales, almost impenetrable to a musket ball. This fierce and formidable creature spares neither man or beast. It springs upon its victim, and not even the tiger can escape its vindictive fury.

3. *The Serpent Tribe.*

Serpents have neither legs, wings, or fins, yet they are, notwithstanding, tolerably swift in their

movements. When we view any of the serpent race, it excites a sensation of horror; for some of them are terrible from their magnitude and strength, and attack both men and animals without distinction. Happily for us, these monsters are not to be met with in Europe; but in the tropical regions, where the climate is sultry and the forests thick, these dangerous reptiles abound.

4. *Boa Constrictor.*

The boa, or liboya, is an enormous serpent, generally thirty feet long, and of a proportionate thickness; its colour is of a dusky white, variously spotted; its scales are round, small, and smooth. When it attacks any animal, it raises itself upright on its tail; and there have been many extraordinary facts related of its powers.

A serpent had been waiting some time near the brink of a pool, in expectation of its prey, when a buffalo was the first victim that presented itself. Having darted upon the animal, it began to wrap itself round it, and at every twist the bones of the buffalo were heard to crack. The poor animal struggled and bellowed; but its terrible enemy encircled it the more closely, till at length all its bones being crushed to peices, the serpent untwined its folds, and swallowed the buffalo at its leisure.

5. *The Rattle Snake.*

The rattle snake possesses the most direful poison, and is distinguished for the fatal effects of its bite and the rattle in its tail, with which it makes a loud noise on the least motion. This rattle is composed of several thin, hard, and hollow bones, linked together, and appears to have been given it by the wise Author of Nature, for the purpose of warning other creatures of its approach. The malignity of its venom is such, that the pain soon grows insupport-

able, and persons who have been bitten, have been known to expire in less than six hours after.

6. All the serpent tribe are not however venomous, the greater part of them acting only on the defensive. The only venomous one which is known to exist in this country is the viper. The common snake is the largest we have, and is perfectly harmless.

Questions for Examination.

1. What are the reptile race, and how divided?
2. Describe those of the lizard kind.
3, 4, 5. Describe also the serpent tribe, and of these the boa constrictor, and rattle snake in particular.
6. Are all the serpent tribe venomous?

SECTION XVIII.

Insects.

The insects most remarkable for their benefits or inconveniences to man are few, though the genus be amazingly large.

The Bee.

1. The Prince of Insects is the bee, and of it we shall say a few words.

The bee is a well known insect, of a brown colour, and rather hairy body. Bees live in numerous societies, either in decayed trees, or in habitations, prepared for them, called hives. Each hive contains a single female, called the queen bee; about 1,600, males, called drones; and above 20,000 of neither sex called working ones. Upon the latter, the whole trouble devolves of constructing the combs

and collecting and forming the honey. Of all winged insects none are more wonderful or more beneficial to man than bees. In some countries bees are an object of great attention to the peasant, and their honey and wax are considerable articles of trade. It would, however, be impossible to enter into particulars in this place: we shall therefore only observe, that their civil and domestic economy, and their unwearied industry, alike entitle them to our regard and imitation.

2. *The Silk Worm.*

The silk worm is an insect resembling a caterpillar, and produces that ornament of our dress so much admired, called silk. As this insect lives but a short time, it is continually employed in spinning its silk, which nature has taught it to perform with such infinite art as to astonish all those who behold it.

3. *The Spanish Fly.*

The Spanish fly, or blistering lytta, is an insect about an inch in length, of a shining blue-green colour. It is found in most parts of Europe, and in South America, and feeds on the leaves of various trees.

They are used in medicine by the name of cantharides, for blistering plaisters, and also as an internal remedy for many diseases. They are imported from Spain and Italy; and as they are generally in a torpid state during the day time, they are easily collected by shaking them from the trees, on a cloth spread underneath for the purpose of receiving them.

4. *The Locust.*

A locust is not much unlike our large grasshoppers in form, and is about two inches and a half in length, with a brownish body, blue legs, and wings of a yellowish brown, spotted with black; they are very common in some parts of the east, and at times do incredible mischief by destroying the produce of the fields and gardens.

The Ethiopians and Parthians are recorded, from the earliest periods of antiquity, to have occasionally subsisted on them. The Hottentots also delight in them, and many of the African tribes dress them in various ways, and consider them a delicacy. In Scripture we are told that the food of St. John the Baptist, in the Wilderness, was "locusts and wild honey."

5. *The Scorpion.*

Among all the insect tribe, the scorpion is the most terrible; its figure is hideous, and its sting is generally fatal. In scripture they are frequently mentioned for their mischievous malignity. In shape, the scorpion somewhat resembles the lobster, but is beyond all comparison most horrible. Its fierceness is dangerous not only to all other creatures, but also to its own species, and two never meet without fighting till one of them is destroyed.

Questions for Examination.

1. Of the insect tribe describe the bee, and particularize its qualities.

2. Describe also the silk worm and enumerate its properties.

3. Also the Spanish fly.

4, 5. Describe now the locust and scorpion.

CHAPTER III.

BOTANY, OR THE SCIENCE OF THE VEGETABLE KINGDOM.

SECTION I.

Introduction to the Science.

1. VEGETABLES are organized bodies, supported by air and food, endowed with life, and subject to death, as well as animals. They have in some instances, spontaneous action, though we know not that they have voluntary motion. They are sensible to the effects of nourishment, air, and light; and they either thrive or languish, according to the wholesome or hurtful application of these stimulants.

This is evident to all who have ever seen a plant growing in a climate, soil, or situation, not suitable to it. He who has ever gathered a rose, knows well how soon it withers; and the familiar application of its fate to that of life and beauty, is not more striking to the imagination, than philosophically and literally true.

2. The history of the Vegetable Kingdom is termed BOTANY, a study which includes the *practical discrimination, methodical arrangement* and *systematic nomenclature* of Vegetables.

3. The external covering of Plants, (the Epidermis or cuticle,) is commonly transparent and

smooth; sometimes it is hairy or downy; and sometimes of so hard a nature that even flint has been detected in its composition.

Illus. The *equisetum hyemale*, or *Dutch rush*, serves as a file to polish wood, ivory, and even brass.

4. Under the cuticle, is found the *cellular-integument*, which is analogous to the *rete mucosum* of animals; it is, like that ,of a pulpy texture, and is the seat of colour. It is commonly green in the leaves and stems, and is independent for its hue on the action of light.

5. When the cellular integument is removed, the *bark* presents itself, which, in plants and branches only one year old, consists of a simple layer. In the branches and stems of trees it consists of as many layers as they are years old.

Illus. The uses of bark are familiar to us. The *Peruvian bark* is a most excellent and useful medicine; whilst that of the *Cinnamon* tree, ranks amongst the most odoriferous spices; and the bark stripped from the oak, is used for the purpose of tanning.

6. Immediately under the bark, is the *wood*, which forms the great bulk of trees and shrubs.

This also consists of numerous layers, as may be observed in the fir, and many other trees; and, from these *concentric circles*, or *rings*, the age of a tree may be determined.

7. Within the centre of the wood, is the *medulla*, or *pith*, which is a cellular substance, juicy when young, extending from the roots, to the summits of the branches.

In some plants, as in *grasses*, it is hollow, merely lining the stem.

8. The trunk enlarges by the formation of the new *liber* [or *inner bark*] every year; the whole of the liber excepting its outermost layer, (which is transformed into the *cortex*, or *outer bark*), becoming the *alburnum*, or soft wood, of the *lignum* or hard wood.

9. In describing the characters of plants, we shall treat of their roots, trunk, buds, leaves, props, inflorescence, fructification, and classification; as in the following sections.

Questions for Examination.

1. Describe what vegetables are.
2 What is the history of the vegetable kingdom called?
3. Describe the external covering of plants.
4. Describe the cellular integument.
5. When does the bark present itself?
6. What is immediately under the bark?
7. What is the medulla or pith?
8. How does the trunk enlarge?
9. Of what do we treat in describing the characters of plants?

Section II.

Of the Roots and Trunk.

1. Roots are necessary to plants, to fix and hold them in the earth, from which they imbibe nourishment.

Roots are either *annual* (or living for one season, as in *barley*:) *biennial*, (or those which survive one winter,

and after perfecting their seed, perish at the end of the following summer, as *wheat ;*) or *perennial*, (as those which remain and produce blossoms for an indefinite number of years,) as those of *trees* and *shrubs* in general.

2. The root consists of two parts, the *caudex*, and the *radicula*. The *caudex* or *stump* is the body or knot of the root, from which the trunk and branches *ascend*, and the fibrous roots *descend*. The *radicula* is the fibrous part of the root, branching from the *caudex*.

Roots are: 1. *Fibrous*, consisting of fibres entirely, as in many grasses and *herbaceous* plants.

2. *Creeping*, or having a subterraneous stem, spreading horizontally in the ground, and throwing out numerous fibres, as in *mint* and *couch-grass*.

3d. *Spindle-shaped*, as in the *radish* and *carrot*, which produce numerous fibres for the absorption of nutriment.

4th. *Stumped*, or apparently *bitten off*, as in the primrose.

5th. *Tuberose*, or nobbed, as in the potatoe, which consists of fleshy nobs connected by common fibres or stalks.

6th. ***Bulbous***, as in the crocus.

7. *Granulated*, or having a cluster of little bulbs or scales connected by a common fibre, as in the saxifrage.

3. Trunk. The trunks of trees include the stems or stalks, which are of seven kinds. The stem, as it advances in growth, is either able to support itself, or twines round other bodies. It is either *simple*, as in the lily ; or ***branched***, as in other plants.

The parts of the trunk are: 1st. *Caulis*, the stem which bears both leaves and flowers, as the trunks and branches

of all trees and shrubs, as well as of many herbaceous plants.

2nd. *Culmus*; the peculiar stem of grasses, rushes, and similar plants.

3rd. *Scapus*, or stalk, springs immediately from the root, bearing flowers and fruit, but not leaves, as in the primrose or cowslip.

4th. *Pedunculus*; the flower stalk, springs from the stem, or branches bearing flowers and fruit, but not leaves.

5th. *Petiolus*, the *foot stalk*, is applied exclusively to the stalk of a leaf.

Questions for Examination.

1. What are the roots of plants?
2. Of what do the roots consist? and of how many kinds are there?
3. Describe the trunk and enumerate its parts.

Section III.

Of the Leaves, Buds, and Props.

1. **Leaves.** These are generally so formed as to present a large surface to the atmosphere.—When they are of any other hue than green, they are said in botanical language to be "coloured" The internal surface of a leaf is highly *vascular* and pulpy, and is clothed with a cuticle very various in different plants; but its pores are always so constructed as to admit of the requisite evaporation or absorption of moisture, as well as to admit and give out air. Light also acts through this cuticle in a different manner. The effects of moisture must have been observed by every

one. By absorption from the atmosphere, the leaves are refreshed; but by evaporation, especially when separated from their stalks, they soon fade and wither. The nutritious juices, imbibed from the earth becoming sap, are carried by appropiate vessels into the substance of the leaves, and these juices are returned from each leaf, not into the wood again, but into the bark. This is effected by a double set of vessels analogous to the arteries and veins in animals, and these vessels are the channels of circulation for the vegetable blood. The sap is carried into the leaves again for the purpose of being acted upon by air and light, with the assistance of heat and moisture.

By all these agents, a most material change is wrought in the component parts of the sap, according to the nature of the secretions which are elaborated, resinous, oily, mucilaginous, saccharine, bitter, acrid, or alkaline.

The green colour of the leaves is almost entirely owing to the action of light, as was before observed. Any leaves are subject to a sort of disease, by which they become partially spotted or streaked, as with white, or yellow, and in this state are termed *variegated*. The innatable nature of leaves is very extraordinary. The *mimosa-pudica*, (or sensitive plant common in hot-houses,) when touched by any extraneous body, folds up its leaves one after another, while the foot stalks droop, as if dying.

2. **Buds.** These are in most instances guarded by scales, and furnished by gum or wooliness, as an additional defence. Buds are various in their forms, but very uniform in the same species or even genus. They unfold the embryo plant.

3. Props or *fulcra*, are 1st. *stipula*, a leafy appendage to the true leaves, or to their stalks, for the most part in pairs.

2nd. *Bractea*, a leafy appendage to the flower or its stalk, very conspicuous in the lime-tree.

3rd. *Spina*, (a thorn) proceeding from the wood itself, as in the wild pear-tree, which loses its stalk by cultivation.

4th. *Aculeus*, a prickle proceeding from the bark only, as in the rose and bramble.

5th. *Cirrus* (a tendril or clasper) is a support for weak stems, and enables them to climb rocks, or the trunks of lofty trees.

6th. *Glandula* (a gland) is a small *tumour*, secreting a sweet, resinous, or fragrant liquor, as on the calyx or cup of the moss-rose, and the foot stalks of passion-flowers.

7th. *Pilus*, (a hair) which includes all the various kinds of pubescence ; bristles, wool, &c. some of which discharge a poison as in the nettle ; causing great irritation whenever they are touched.

Questions for Examination.

1. Describe what leaves are, their construction, uses and properties.
2 Also the properties of buds.
3 And repeat what is said of props.

Section IV.

Inflorescence and Fructification.

1. Inflorescence, or the different kinds or modes o flowering are,

1st. *Verticillus*, (a whirl) in which the flowers surround the stem in a garland or ring, as in the mint, dead-nettle, &c.

2nd. *Racemus*, (a cluster) in which case several flowers are borne each on its own stalk, like a bunch of currants.

3rd. *Spica*, (a spike) of numerous crowded flowers, ranged along an upright common stalk, expanding progressively, as in wheat and barley.

4th. *Corymbus*, (is a flat-topped spike) as in the cabbage and the wallflower.

5th. *Fasciculus*, (a close bundle of flowers) as in the sweet-william.

6th. *Capitulum*, (a head or tuft,) as in the *globe amaranthus*.

7th, *Umbella*, (consists of several stalks called rays, spreading like an umbrella) as in *carrot* and hemlock,

8th. *Cyma*, (or stalks springing from a common centre, and afterwards irregularly subdivided) as in the laurustinus and elder.

9th. *Paniculus*, (a loose subdivided bunch of flowers) as in the oat.

10th. *Thyrsus*, (a stalk) is a very dense bunch, inclining to an oval figure as in the lilac.

2. Fructification. Under this term are comprehended not only the parts of the fruit, but also those of the flower, which last are indispensable for bringing the former to perfection.

3. The parts of fructification are ;

1st. The *calyx*, or cup, an external covering of the flower: to which belong, the perianthium involucrum, amentum, or cat-kin; spatha, or sheath, glima or husk, perichœthium, or scaly sheath; and volva the wrapper.

2nd. The *Corolla*, situated within the calyx, consists in general of the coloured leaves of a flower; the petalum, or petal, and the nectarium or nectary, belong to the corolla.

3rd. The *Stamina.* The stamens vary in number in different flowers, and are situated withinside of the corolla. The stamen consists of a filamentum or filament, and the anthera or anther. The cells of the latter contain the pollen or *fecundating dust.*

4th. The *Pistilla* or pistils stand in the centre of the circle formed of the stamens, and consist of the germen or *rudiments of the future seed, or fruit;* the style which elevates the stigma; and the stigma which is destined to receive the pollen.

5th. The *Pericarpium*, or seed vessel which is formed from the germen enlarged, and is of the following kinds: a *capsular* or capsule; *siligna* or pod; *legumem* or legume, the fruit of the pea kind; *dupa*, stone-fruit; *pomum*, an apple; *bacca*, a berry; and *strobilus*, a cone.

6th. The *Semina*, or seeds, which are composed of the *embryo or germ*, called by Linnæus corculum, or *little heart;* the cotyledones, or *seed-lobes*, almost universally two in number; *al-*

bumera, the *white; vitellus* the *yolk; testa*, the skin; and *hilum*, the scar.

Seed are often accompanied by appendages or accessory parts; as pellilcula, the pellicle; arrillus, the tunic; pappus, the seed-down; cauda, a tail; rostrum a beak. To which may be added various spines, hooks, scalps, and crests, generally serving to attach such seeds as are furnished with them to the rough coats of animals, and thus promote their dispersion.

7th. *Receptaculum.* The receptacle is the base which receives the other parts of the fructification. It is *proper* when it supports the single part of a fructification only; when it is a base, to which only the parts of the flower are joined, the germen being placed below the receptacle of the flower, the germen is called a *receptacle of the flower;* and it has a base of its own which is called the *receptacle of the fruit;* it is termed a *receptacle of the seeds*, when it is a base to which the seeds are fastened, within the pericarpium. It is called common when it supports head of flowers.

Questions for Examination.

1. Describe the different kinds or modes of flowering in plants?
2. What is the fructification of plants?
3. Describe separately the parts of fructification; as the *calix*, the *corolla*, the stamina, &c.

SECTION V.

Plants divided into Classes.

1. For the more easy comprehension of the science of Botany, LINNÆUS divided the whole

vegetable creation into *twenty-four classes*. These are again divided into *orders*, and the ORDERS are subdivided into *genera*, or tribes; and these genera are further divided into *species*, or individuals.

2. A CLASS resembles an *army;* an ORDER, a *regiment;* a GENUS, a *company;* and a SPECIES, a *soldier*.

3. The characters of the classes are taken from the number, connexion, length, or situation of the stamens.

4. In each of the first twenty classes there are stamens and pistils in the same flower; in the twenty-first class they are in distinct flowers on the same plant; in the twenty-second, in distinct flowers on different plants; in the twenty-third, they are in the same flower, as well as in distinct ones; and they are not at all to be seen in the twenty-fourth class.

5. The names of the classes are formed from Greek words, and express the characteristics of each class. The first ten classes are named from the Greek numerals, and the word *andria*, which means the same as stamens.

Classes.

1. Monandria - -	One Stamen.
2. Diandria - - -	Two Stamens.
3. Triandria - -	Three Stamens.
4. Tetrandria - -	Four Stamens.
5. Pentandria - -	Five Stamens.
6. Hexandria - -	Six Stamens.
7. Heptandria - -	Seven Stamens.

8	Octandria	Eight Stamens.
9.	Enneandria	Nine Stamens.
10.	Decandria	Ten Stamens.
11.	Dodecandria	Twelve Stamens.
12.	Icosandria	Twenty Stamens.
13.	Polyandria	Many Stamens.
14.	Didynamia	Four Stamens, two longer.
15.	Tetradynamia	Six Stamens, four longer.
16	Monadelphia	Filaments united at bottom, but separate at top
17.	Diadelphia	Filaments in two sets.
18.	Polyadelphia	Filaments in many sets.
19	Syngenesia	Stamens united by anthera.
20	Gynandria	Stamens and pistils together.
21.	Monœcia	Stamens and pistils in separate flowers, upon the same plant.
22.	Diœcia	Stamens and pistils distinct, upon different plants.
23.	Polygamia	Variously situated.
24.	Cryptogamia	Flowers invisible.

Description of these Classes.

6. All plants which have only one stamen, are of the first class; those that have only two, are of the second; those that have only three, are of the third; and so on. The number of stamens in the first ten classes, with the number of the class corresponding.

The eleventh class contains such plants as have from twelve to nineteen stamens.

The twelth class is known by having twenty or more stamens, fixed to the inside of the calyx. In this class the place of insertion is more to be relied on than the number of the stamens, for there are sometimes less than twenty, and sometimes more.

In the thirteenth class are comprehended those that

have more than twenty stamens attached to the receptacle.

When there are four stamens in a flower, of which two are longer than the others, it belongs to the fourteenth class.

The fifteenth class. (Tetradynamia), is known by having six stamens in a flower, four of which are longer than the other two.

In the sixteenth class the stamens are united by their filaments into one set, forming a case round the lower part of the pistils, but separating at the top.

In the seventeenth class the corollas are papilionaceous, as the blossom of a pea, or like in colour to a butterfly; the stamens are collected by their filaments, but divided into two sets, one of which is thicker, and forms a case round the pistil; the other is smaller, and leans towards the pistil.

In the eighteenth class the stamens are united by their filaments into more than two parcels.

Syngenesia (the name of the nineteenth) consists of compound flowers, as the common daisy or dandelion. They are called compound, because each flower consists of a collection of flowers, attached to the same broad receptacle, and contained within one calyx.

In the twentieth class the stamens are attached to the pistil.

The twenty-first class, (Monœcia) contains such plants, as have flowers of different kinds on the same plant, some bearing pistils, and others stamens only.

The twenty-second class consists of such as have stamens on one plant, and pistils on another.

The twenty-third class comprehends those plants that have at least two kinds of flowers. 1. Some with pistils and stamens in the same flower. 2. Others having stamens only. 3. Or having flowers with pistils only.

The twenty-fourth class (Cryptogamia) comprehends all plants in which the flowers are invisible to the naked eye, such as mosses, ferns, mushrooms, sea-weeds, &c.

Questions for Examination.

1. How has Linnæus divided plants?
2. What does a class, an order, a genus, and a species respectively resemble?
3. Whence are the characters of the classes taken?
4. What are the characters of the several classes?
5. How are the names of the classes formed?
6. What plants belong to each class, and how are they known in the fields.

SECTION VI.

Of the orders of Plants.

1. THE orders are formed on principles, as ingenious and simple as the classes. In the first thirteen classes, the orders are founded on the number of the pistils; so that by adding *gynia* instead of *andria*, to the Greek words signifying the numbers, we have the name of the orders. But where they are not distinguished by the number of the pistils, their names are taken from some circumstances relative to the stamen, pistils, or seed.

Monogynia - - - - -	1. Pistil.
Digynia - - - - - -	2. Pistils.
Trigynia - - - - - -	3. Pistils.
Tetragynia - - - - -	4. Pistils.
Pentagynia - - - - -	5. Pistils.
Hexagynia - - - - -	6. Pistils.
Heptagynia - - - - -	7. Pistils.
Octagynia - - - - -	8. Pistils.
Ennegynia - - - - -	9. Pistils.
Decagynia - - - - -	10. Pistils.
Dodecagynia - - - -	12. Pistils.
Polygynia - - - - -	Many Pistils.

2. In the fourteenth class there are but two orders, which depend on the presence or absence of the pericarp or seed vessel.

1. Gymnospermia. Naked seeds in the bottom of the calyx; as, in mint, dead nettle, and thyme.

2. Angiospermia. Seeds enclosed in a pericarp; as, in fox-glove, eye-bright, wood-flax, and fig-wort.

3. In the fifteenth class there are only two orders which are taken from a difference in the form of the pericarp.

1. Siliculosa. Seeds enclosed in a silicle, or roundish seed-vessel, consisting of two pieces called valves, and the seeds fixed to both edges, or sutures, as in shepherd's purse and cress.

2. Siliquosa. Seeds enclosed in a silique, or long seed-vessel; as in mustard.

4. In the next four classes, *monadelphia*, *diadelphia*, *polyadelphia*, and *gynandria*, the orders are distinguished by the number of stamens; viz. *pentandria*, five stamens; *hexandria*, six stamens, &c.

5. There are six orders in the nineteenth class, which are taken from the structure of the flower.

1. *Polygamia Æqualis*: having both stamens and pistils in the same floret; as in dandelion, thistle, &c.

2. *Polygamia Superflua*; when the flower is composed of two parts—a disk or central part, and rays or petals projecting outwards; as in the sun-flower, tansy, daisy, camomile, &c.

3. *Polygamia Frustranea*; the florets of the centre perfect or united; those of the margin without either stamens or pistils; as blue-bottles.

4. *Polygamia Necessaria ;* where the florets in the disk, though apparently perfect, are not really so, and therefore produce no perfect seed ; but the fertility of the pistilliferous froscules in the ray, compensates for the deficiency of those in the centre of the flower ; as in the marygold.

5. *Polygama Segregata ;* when each of the florets has a calyx, besides the common or general calyx of the flower.

6. *Monogamia ;* when the flower is not compound, but single, and the anther united.

6. In the next three classes *gynandria, manœcia*, and *diœcia*, the orders are formed from the number, and other peculiarities of the stamens:

Monandria - - -	1 Stamen.
Diandria - - - -	2 Stamens, &c.
Polyandria - - -	7 Stamens,
Monadelphia - -	Stamens united into one set.
Polyadelphia - - - -	Stamens united into different sets.
Gynandria - - -	Stamens upon the pistil.

7. The twenty-third class (polygamia) comprises three orders, namely, *monœcia, diœcia*, and *triœcia.*

8. In the last class the orders are four ; ferns, mosses, sea-weeds, and funguses.

Questions for Examination.

1. On what is the formation of the orders founded, in the first 13 classes ?

2. On what do the two orders of the 14th class depend ?

3. On what also are the two orders of the 15th class founded ?

4. How are the orders distinguished in the next 4 classes ?

5. How many orders are there, and how distinguished in the 19th class ?

6. On what are the orders founded in the next 3 classes?
7. What orders does the 23d class comprise?
8. What orders belong to the last class?

SECTION VII.

Particular description of the Classes Monandria, Diandria, and Triandria

Class I. Monandria.

1. Most of the plants belonging to this class are natives of India, such as ginger, arrow-root, turmeric; but the hippuris, or mare's tail, which grows in the muddy pools and ditches of Britain, will serve for an example. It has neither calyx nor corolla.

Its single stamen grows upon the receptacle, terminated by an anther slightly divided, behind which is the pistil, with an awl-shaped stigma, tapering to a point. The stem is straight and jointed, the leaves grow round the joints, and at the base of each leaf is a flower, which blossoms in May.

Class II. Diandria.

2. In this class we reckon the privet (ligustrum), a shrub common in the hedges and gardens of Britain. It will therefore serve to exemplify this class.

The privet bears a white blossom and flowers in June. It has a very small tubulated calyx of one leaf, the rim of which is divided into four parts. The blossom consists of one petal, funnel-shaped, with an expanded border, cut into four egg-shaped segments.

It is known to belong to this class by its having two stamens placed opposite to each other, and nearly as long as the blossom. The seed bud is roundish, the pistil or style short, terminated by a thick, blunt, cloven stigma. The leaves grow in pairs, and are sometimes variegated with white or yellow stripes.

It bears berries, the seed-vessel is a black berry, which contains only one cell, enclosing four seeds. These berries give a durable green colour to silk or wool, by the addition of alum.

Class III. Triandria.

3. We will illustrate this class by giving an account of some of the various grasses which are comprised in it; every blade of these apparently insignificant plants bears a distinct flower; and there are upwards of three hundred species of grasses.

The general character of grasses may be thus described: the leaves furnish pasture for cattle; birds feed on the smaller seeds, and the larger are food for man; but some are preferred to others: as fescue, for sheep; meadow-grass, for cows; canary, for small birds; oats and beans for horses; rye, wheat, and barley, for man.

And almost all our most important articles of food and clothing are derived from them; as for example, bread, meat, beer, milk, butter, cheese, leather, and wool; and to them we owe all the advantages produced from the use of cattle.

4. *Grasses* are distinguished from other plants by their simple, straight, unbranched stalk, hollow and jointed, commonly called a straw, with long, narrow, tapering leaves, growing out at each knob or joint of the stalk, and sheathing or

enclosing it, by way of support: their ears or heads consist of a husk, generally composed of two valves, which form the calyx; within this is the blossom, being also a husk of two valves.

5. *Linnæus* has arranged the various grasses into four divisions; the first three include those that are produced in pannicles, or loose branches, which are distinguished by the number of flowers in each empalement; the first having one flower; the second, two; and the third, several. The fourth division consists of all those that grow in spikes or heads, such as wheat, rye, barley, &c.

Wheat, the chief support of man, is cultivated in all the civilized countries of the world, and is supposed to have been originally introduced into Europe from Asia.

6. Belonging to this class is the sugar-cane, (saccharum officinarum) a plant much cultivated in the East and West Indies. The sugar-cane has a jointed stem eight or nine feet high, long and flat leaves of a greenish yellow colour, and flowers in bunches.

When cut down, the leaves are thrown away, and the stems or canes are divided into pieces, each about a yard in length; they are then tied up in bundles, and conveyed to the mill, where they are bruised between three wooden rollers, fixed perpendicularly, and covered with iron. The saccharine juice which flows from them is conducted into a large vessel; it is then boiled in large caldrons, and afterwards carefully drawn off, to leave the scum at the bottom of the pan. After being again boiled with a mixture of lime, the juice is racked off into a large shallow wooden vessel, where as it cools, it chrystallizes, by which

it is separated from the molasses or treacle, an impure part of the juice, incapable of crystallization, but which is used for various domestic purposes.

Questions for Examination.

1. What plants belong to the 1st class? and of these how do you describe particularly the *hippuris* or mare's tail?
2. Of the 2nd class, describe the *privet*?
3. How do you illustrate the 3rd class triandria? What articles of food and clothing are taken from the products of this class?
4. What are the distinguishing characteristics of this class?
5. How has Linnæus arranged the different grasses?
6. Describe the sugar-cane, and tell me how the sugar is extracted from it and prepared for use?

SECTION VIII.

Particular description of the Classes Tetrandria and Pentandria.

Class IV. Tetrandria.

1. The flowers of this class are characterized by having four stamens, as teasel, madder, ladies' bedstraw, and holly.

2. Teasel, (dipsacus fullonum) is a plant cultivated in several parts of England, and used in the carding of woollen cloths. It is distinguished from other plants of the same tribe, by having its leaves connected at the base; the flower scales hooked; and the general calyx reflected or bent back.

6. Holly (ilex aquifolium) is a small evergreen tree, with shining irregular leaves and white flowers, which grow in clusters round the branches, and are succeeded by small red berries; holly is very serviceable as a fence, it retains its verdure through the severest winters. The wood is close grained, and is used for many purposes. The leaves afford a grateful food to sheep and deer in winter; and the berries to numerous birds.

We use branches of holly to decorate our houses and churches at Christmas, to give an air of spring in the depth of winter. The holly-bush seems, however, to takes its name from this custom, *Y-ule* or *Hule.*—Holy, or holiday was the day of Christmas; hence the bush that day was *Hule holy,* hollybush.

Class V. Pentandria.

4. In this class is comprised one-tenth of the vegetable kingdom; and it includes numerous agreeable flowers as well as noxious plants. The primrose, oxlip, cowslip, and polyanthus, belong to it: and also the tribe of plants called luridæ. This name is expressive of their noxious appearance and strong scent.

The polyanthus, so much cultivated by florists, is derived from the primrose; and is a pleasing instance of the improvement that art can bestow on nature. The species is marked by a five-angled calyx, the wrinkled surface and indented edges of its leaves.

5. The plants belonging to the tribe luridæ have the characteristic marks of five stamens and

one pointal, they coincide in a calyx that is permanent, and divided, like the corolla, which consists of one petal, into five segments. Their seed-vessel is either a capsule or a berry, enclosed within the flower.

As an example we will take the deadly night-shade (atropa belladonna) which is the most fatal of any in its effects. The leaves are egg-shaped and undivided, and the blossoms of a dingy purple. Woods, hedges, and gloomy lanes generally conceal this dangerous plant; whose bright, shining, black berries have too frequently tempted children to partake of its dangerous poison.

The thorn apple (datura); henbane (hyosycamus), the smell of which is exceeding disagreeable; the night-shade (solanum) which comprises two kinds, the woody night-shade, known by its blue blossoms and red berries; the garden night-shade, distinguished by its white blossoms and black berries.

Questions for Examination.

1. Describe the 4th class?
2. Describe teasel?
3. Also holly, and whence its name?
4. How is the 5th class particularly described? Whence is the polyanthus derived? and how known?
5. What characteristics have the plants belonging to this class? And describe the deadly night-shade, &c.

Section IX.

Particular description of the Classes, Hexandria, Octandria, Enneandria, and Decandria.

Class VI. Hexandria.

1. Our gardens receive most splendid embellishments from flowers of this class; as, for ex-

ample, the gaudy tulip, with its striped coat of various hues; the hyacinth, of different colours, and delightful fragrance; lilies of every kind; the magnificent amaryllis; and the great American aloe, which rises to the height of twenty feet. Many of our smaller garden flowers also belong to this class, as the modest snow-drop, the golden crocus, the innocent and fragrant lily, the daffodil, narcissus, and many others.

The snow drop (galanthus nivalis) is one of the earliest harbingers of spring, and this beautiful little flower never appears to more advantage than when it intermixes its blossoms with those of the golden crocus, to which it is nearly allied, in its manner of growth and external structure.

Class VII. Heptandria.

2. Of this class is the horse-chesnut tree, (æsculus hippocastanum) very common in parks and pleasure grounds, bearing elegant pyramidal clusters of flowers. This is certainly one of the finest trees of British growth; and its fruit, which is contained in pricky husks, is of considerable service in fattening cattle.

Its botanical characters are a small calyx, of one leaf, slightly divided at the top into five segments, and swelling at the base; a corolla of five petals, inserted in the calyx, and a capsule of three cells, in one or two of which only is a seed.

Class VIII. Octandria.

3. This class comprises various foreign and native shrubs; among the former are the balm

of Gilead shrub, a native of Abyssinia and Syria; the sugar-maple of North-America, which is fifty or sixty feet high; and the rose-wood tree in the island of Jamaica; which, besides yielding an odoriferous balsam is much used by our cabinet-makers, for veneering tables, &c.

The plants of the native tribe are the common maple and sycamore trees, the cranberry and whortleberry shrubs, and the common heaths.

Class IX. Enneandria.

4. This class includes several foreign plants, such as cinnamon, cassia, sassafrass, bay, camphor, and rhubarb; but we have only one plant that belongs to it, growing wild in this country, which is the flowering rush (butomus umbellatus).

The flowering rush grows in the water, and has a round smooth stalk, which according to its situation rises from one to six feet high, the top is surmounted by a tuft of bright red flowers, sometimes not less than thirty; three short leaves spring from the cup; the corolla has six petals. This plant so hardy as to defy the severest frost, and so stately from its height, and its beautiful tuft of flowers, would make a charming appearance in canals, or other pieces of water, if cultivated by art.

Class X. Decandria.

5. In this class are ranked several trees of foreign growth, as well as various plants and flowers common to Britain. The lignum-vitæ tree, logwood, and mahogany, all natives of the West-Indies, belonging each to this class.

The mahogany tree is of large dimensions, with winged leaves and small white flowers; its branches are numerous and spreading; its leaves are alternate and winged, with four or five pairs of leaflets, somewhat spear-shaped. It grows in Jamaica and Honduras. A single tree has been known to yield twelve thousand superficial feet, and to have produced £1000 sterling. The body of the tree is of course the most valuable part; but, for ornamental purposes, the limbs are preferred, as the veins are more variegated, and the grain is closer.

6. The flowers belonging to this class are, the rich carnation, the modest sweet-william, and the whole tribe of pinks.

Questions for Examination.

1. What plants belong to the 6th class, and how are they particulurly distinguished? Among these pray describe the snow-drop.

2. What plants belong to the 7th class, and how are they particularly distinguished? And what are the botanical characters of the horse-chesnut?

3. Describe the plants which belong to the eighth class. Also the native plants belonging to this class.

4. What plants belong to the 9th class? Describe the flowering rush.

5. What trees are comprised in the 10th class? Describe the mahogany tree?

6. What flowers belong to this class?

SECTION X.

Particular description of the Classes, Dodecandria, Icosandria, and Polyandria.

Class XI. Dodecandria.

1. This class furnishes no example more va-

luable or interesting than weld, or dyer's weed, which is found on barren ground, or on walls; and in the clothing counties in England, is cultivated to a considerable extent. Its leaves are spear-shaped, and entire, with a tooth-like process on each side of the base. The flowers are yellow, in long spikes; and the calyx is divided into four segments.

It affords a fine yellow dye, which is procured from the roots and stems; and blue cloth dipped in a decoction of this dye, become green. The paint, called Dutch-pink, is also obtained from this plant. It is said that the ancient Britons used to stain their bodies with the dye of weld.

Class XII. Icosandria.

2. To this class belong a great variety of fruit trees, such as the apple, pear, cherry, plum, nectarine, peach, almond, and medlar. Also various shrubs and herbs, such as laurels, roses, strawberries, &c.

The *magnum bonum*, the green gage, and several other fruit trees of exquisite flavour, now common in our gardens, have received their parent stock from the wild plum.

3. To this class belongs the rose, one of the most elegant and fragrant of all vegetable productions. The rose for that reason, has been denominated the queen of flowers. That elegant perfume called otto of roses, is extracted from its petals by distillation; but so small a quantity of this aromatic oil can be procured, that the genuine otto is exceedingly dear, an hundred pounds weight of the flowers, yielding only half an ounce of oil.

Class XIII. Polyandria.

3. In this class we may enumerate the poppy

and the tea tree. From the former opium and laudanum are produced; the latter affords us a beverage drank by all classes of society.

Opium is produced from the seed vessels of the poppy, in which several gashes are made, and a milky fluid exudes, which when it attains sufficient consistence is formed into balls or cakes, and is of a dark brown colour. Its uses in medicine, to cause sleep, and alleviate pain, are well known. Laudanum, a liquid preparation from opium and spirits of wine, is used for the same purposes. And I think the black drop is a preparation of opium, and thieves' vinegar.

The tea tree, an evergreen shrub, about five or six feet high, and much branched, flourishes with great luxuriance in valleys, on the sloping sides of hills, and on the banks of rivers, in the mildest and most temperate parts of China. The leaves are narrow and tapering; the flowers, like those of the wild rose, but smaller, are succeeded by a fruit about the size of a sloe, containing two or three seeds.

Questions for Examination.

1. Describe the weld or dyer's weed, belonging to the 11th class.

2. What fruit trees belong to the 12th class? and what is recorded of the rose, as belonging to this class.

3. Belonging to the 13th class, describe the poppy and tea tree; aud tell me how opium is made, and what are its uses.

Section XI.

Particular description of the Classes Didynamia, Tetradynamia, Monadelphia, and Polyadelphia.

Class XIV.—Didynamia.

1. Many of the plants comprising this class and distinguished by us as garden herbs are valued

for their odoriferous smell and kitchen uses, as well as for the medicinal qualities which some of them possess.

Thus, common or spear mint (mentha viridis), a common garden herb, is a native British plant, that grows wild in watery places and near the banks of rivers. Its flavour is peculiarly agreeable, and, on this account, it is preferred for many culinary purposes. The leaves are used in spring salads, are boiled with peas, and, mixed with vinegar, they form a sauce for lamb.

Class XV.—Tetradynamia.

2. The plants which compose this class are all eatable, and generally possess anti-scorbutic qualities. In this class we find the the cabbage, the turnip, the water-cress, and mustard, with a variety of wild plants and flowers.

Common mustard is made from the powdered seeds of a plant (sinapis nigra), which in most parts of England grows wild in corn-fields, and by the sides of the highway. This plant is known by its yellow cruciform flowers, with expanding calyx; its pods are smooth, square, and close to the stem. In light lands it is cultivated to great advantage; the county of Durham produce the best in England. We use mustard at our tables; its seeds are used in pickles, and preparations from it are employed in medicine, both internally and externally.

Class XVI.—Monadelphia.

3. In this class we have no example more interesting than the cotton plant, which is cultivated in the East and West Indies, and other hot countries. This plant grows to a considerable height, and has leaves of a bright green colour; its

flowers have only one petal, of a pale yellow colour, with five red spots at the bottom; the seed vessels or cotton pod, containing a soft vegetable down, which envelopes the seeds.

After being gathered, and carefully separated from the seeds, it is packed in bags for exportation. In this country it undergoes the processes of carding, spinning, and weaving into cloth.

Class XVII.—Diadelphia.

4. In this class there are many plants well known to us, such as peas, beans, vetches, clover, lucern, broom, furze, &c.; but a description of one of them will be sufficient. They are called papillionaceous, from the butterfly-like colour of their flowers.

Thus, the common broom, seen on sandy heaths in most parts of England, has large yellow butterfly-shaped flowers, with leaves in threes; the branches are without prickles. This shrub is distinguished from furze, which consists of a cup with two leaves, and is still more common here than broom, though in some other countries it is rarely seen.

Class XVIII.—Polyadelphia.

5. The plants arranged in this class are several foreign fruit trees, as the orange, the lemon, the citron, and the cocoa trees.

Of the orange and lemon shrubs, evergreen plants, the latter has large and slightly indented shining leaves, somewhat oval-shaped, but pointed; the flowers are large and white, but of a purplish hue on the outside of the petals,

The orange tree has a winged appendage on the leaf stalks, the lemon tree is destitute of this appendage.

Oranges are extremely grateful, and wholesome; in fevers and other complaints, in allaying heat and quenching thirst. The juice of lemons, sharp and agreeable, is used in cookery, confectionary, and medicine.

Questions for Examination.

1. What plants belong to the 14th class? and of these describe common peppermint.
2. What are the plants of the 15th class? and of these, how is common mustard cultivated?
3. What plants belong to the 16th class? and how do you describe the cultivation of cotton?
4. What plants belong to the 17th class? and of these describe the common broom.
5. What plants are arranged under the 18th class? and among these describe the orange and lemon trees.

Section XII.

Particular description of the Classes Syngenesia, Gynandria, Monœcia, Diœcia, Polyamia, and Cryptogamia.

Class XIX.—Syngenesia.

1. Under this class we rank the daisy, which so delightfully enamels every meadow; there is much beauty and variety discernible in this little flower. The calyx is formed of a double row of spear-shaped leaves; the numerous tubular yellow florets in the centre are furnished with both stamens and pistils, while those composing the ray, which are white above and pink beneath,

contain pistils only. The receptacle is naked and conical, and a naked stalk supports a single flower.

Class XX.—Gynandria.

2. Several well-known field plants of the *orchis* tribe belong to this class; they have an oblong withered germ below the flower, which has no proper calyx, but only sheaths; the corolla consists of five petals, the two innermost of which usually join to form an arch or helmet over the top of the flower. In some species, the root is composed of a pair of solid bulbs, in others it consists of a set of oblong fleshy substances, tapering towards the ends.

Class XXI.—Monœcia.

9. Among the plants comprised in this class we notice a variety of trees and plants, both native and foreign, as the oak, birch, alder, beech, walnut, sweet chesnut, fir, hazel nut, filbert, and mulberry trees, and the numerous kinds of native sedges. In the list of foreign plants, the breadfruit tree, the cork tree, the cocoa-nut tree, the tallow tree, maize or Indian corn, hold conspicuous places.

Class XXII.—Diœcia.

4. In this class there are many varieties of willow; but the one most remarkable for its singularity is the round-leafed willow. Its leaves are smooth, en-

tire, and egg-shaped; the upper surface is green and wrinkled; the under one is bluish, and covered with net-work of veins, which are at first red, but afterwards become green. It is but a low shrub, and produces both flowers and leaves from the same bud.

Class XXIII.—Polygamia.

5. In this class we reckon the plaintain tree, than which, to the negroes of the West Indies, there is no production more serviceable. The stem of this tree grows to the height of twenty-feet, with several leaves on the summit, about eight feet long, and two feet broad, but remarkably thin and tender. The fruit, of a pale yellow colour, is produced in bunches that weigh about forty pounds.

The fruit serves the negroes as bread. It is usually gathered before it is ripe, and after the skin has been peeled off, it is slightly roasted in a clear fire, and then scraped and eaten as bread.

Class XXIV.—Cryptogamia.

6. This class comprises all plants in which the flowers are inconspicuous, such as mosses, ferns, fungusses, and among the latter, mushrooms are of course included.

Though several kinds of mushrooms are edible, many are extremely poisonous. An emetic is the best remedy that can be administered in cases of injury from poisonous fungusses.

Questions for Examination.

1. Describe the daisy, as belonging to the 19th class.
2. What are the particulars of the 20th class?
3. What plants belong to the 21st class?
4. What plants belong to the 22d class? What of the willow?
5. Belonging to the 23d class, describe the plaintain.
6. Belonging to the 24th class, describe the mushroom.

Section XIII.

Of the Method of forming an Herbarium, or Hortus Siccus, on the scientific principles established in Pinnock and Maunder's, "Catechism of Botany."

1. It has been observed by the best writers on Botany, that every person that wishes to become a complete Botanist, will find it necessary to preserve, and to form into a collection, the plants which he has examined.

2. The best method of preserving them is by drying them; specimens ought to be collected when dry, and carried home in a tin box. Plants may be dried by pressing, in a box of sand, or with a hot smoothing iron. Each of these has its advantages.

3. If pressure be employed, a botanical press may be procured; the press is made of two smooth boards of hard wood, eighteen inches long, twelve broad, and two thick. Screws must be fixed to each corner, with nuts. If a press cannot easily be had, books may be employed.

4. Next, some quires of unsized blossom blotting paper must be provided. The specimens when taken out of the tin box, must be carefully spread on a piece of paste board, covered with a single sheet of the blossom paper quite dry; then place three or four sheets of the same paper above the plant, to imbibe the moisture as it is pressed out; it is then to be put into the press. As many plants as the press will hold may be piled up in this manner. At first they ought to be pressed gently.

5. After being pressed for twenty-four hours or so, the plants ought to be examined, that any leaves or petals which have been folded may be spread out, and dry sheets of paper laid over them. They may now be replaced in the press, and a greater degree of pressure applied. The press ought to stand near the fire, or in the sunshine. After remaining two days in this situation, they should be again examined, and dry sheets of paper be laid over them. The pressure then ought to be considerably increased. After remaining three days longer in the press, the plants may be taken out, and such as are sufficiently dry may be put in a dry sheet of writing-paper. Those plants which are succulent may require more pressure, and the blossom paper again renewed.

6. Plants which dry very quickly, ought to be pressed with considerable force when first put in the press; and, if delicate, the blossom paper

should be changed every day. When the stem is woody, it may be thinned with a knife, and if the flower be thick or globular, as the thistle, one side may be cut away; as all that is necessary in a specimen, is to preserve the character of the class, order, genus, and species.

7. Plants may be dried in a box of sand in a more expeditious manner; and this method preserves the colour of some plants better. The specimens, after being pressed for ten or twelve hours, must be laid within a sheet of blossom paper. The box must contain an inch deep of fine dry sand, on which the sheet is to be placed, and then covered with sand an inch thick: another sheet then may be deposited in the same manner, and so on, till the box be full. The box must be placed near a fire for two or three days. Then the sand must be carefully removed, and the plants examined. If not sufficiently dried, they may again be replaced in the same manner for a day or two.

8. In drying plants with a hot smoothing iron, they must be placed within several sheets of blotting paper, and ironed till they become sufficiently dry. This method answers best for drying succulent and mucilaginous plants.

9. When properly dried, the specimens should be placed in sheets of writing-paper, and may be slightly fastened by making the top and bottom of the stalk pass through a slip of the paper, cut neatly for the purpose. Then the name of the genus and species should be written down, the

place where it was found, nature of the soil, and season of the year. These specimens may be collected into genera, orders, and classes, and titled and preserved in a portfolio or cabinet.

Questions for Examination.

1. What will every person, wishing to become a complete botanist, find it necessary to do?
2. What methods are employed to preserve specimens of plants?
3. What is the process of preservation by *pressure,* or the botanical press?
4. How do you proceed with the specimens when taken out of the tin box?
5. What is the next step of your process after the plants have been pressed for twenty-four hours.
6. How do you deal by *plants* which *dry* in pressing?
7. How may the plants be dried in the sand box?
8. What is the process of drying with a hot smoothing iron?
9. How are your specimens displayed and collected when properly dried?

Note. In the sequel of this volume, under the title Chemistry, the student will find an entire section devoted to an examination of the constituent parts of vegetables; and which being purely a chemical analysis, could not come in here.

CHAPTER V.

GEOLOGY, OR THE MINERAL KINGDOM.

Section I.

1. In taking a general view of the substances which encrust our globe, we perceive certain distinctions of texture and disposition, both curious and important; the knowledge of these constitutes the science of Geology. All rocks are divided into three classes, *primitive, transition, and secondary.*

Primitive.

2. Primitive rocks are large masses or blocks, not regularly stratified, but affecting a vertical arrangement in their fractures. Sometimes they are of a perfectly homogeneous texture, hard and

durable, and sometimes composed of several ingredients blended together; they are generally crystaline in their texture, and constitute the loftiest mountains.

Transition.

3. Transition rocks, or those next, in point of antiquity, are less lofty than the primitive. In many instances, they present a slaty texture, and seem to have been deposited in stratas or layers, variously inclined to the horizon.

Secondary.

4. Secondary rocks, or the more recent series, are horizontal in their positions. In texture they are soft, easy of decay, and appear to be mechanical deposits rather than chemical compounds resulting from fusion, crystallization, or solution.

In the figure which is placed at the head of this chapter, I have endeavoured to represent these formations, as well as the general features of a geological survey.

Granite.

5. Granite belongs to the series of primitive rocks; it is the most abundant and useful. It has obtained this name from its being composed of distinct grains or particles. Its component parts are quartz, felspar, and mica.

6. Quartz, or rock crystal, consists of pure siliceous earth. It is found in more or less regular six-sided prisms, terminated by pyramids, and of various colours, such as rose, brown, yel-

low, and purple ; metallic oxydes generally giving it those tints.

These varieties are sometimes transparent, and when properly cut, constitute beautiful articles of ornamental jewellery. They are so hard as not be scratched by a knife, and they will cut glass.

Obs. 1. Silex or flint is an important substance in the arts, and an ingredient in glass, earthenware, and porcelain.

2. Chalcedonies, agates, and jaspers consist principally of siliceous earth ; the term quartz is especially applied to the purer varieties.

3. Quartz is sometimes met with in masses of a conical appearance. It is sometimes white, and of a more or less granular texture. The Sugar-loaf mountains near Dublin, the Pass of Jura, and some of the mountains of Sutherland and Caithness, present instances of this formation.

7. Felspar is a compound body, of which silex and alumine are the ingredients, though it generally contains a little lime and potash, and is often coloured by oxyde of iron ; sometimes, however, it is found crystalized, in four and six-sided prisms. Its colours are red, white, and grey. It is softer than quartz, but harder than glass, and fuses before the blowpipe.

Obs. 1. Felspar is an ingredient in pottery ; and that of Cornwall (employed in the English porcelain manufactories, because it contains no iron), retains its perfect whiteness, like the Chinese petnutz.

2. Siberia and America furnish the green and blue felspar employed in jewellery. The beautiful foliated, pearly, and resplendent varieties, called adularia and moonstone, and the felspar of the island of St. Paul, upon the coast of Labrador, are distinguished by the property of reflect-

ing beautiful colours when light falls upon them in certain directions.

8. Mica is a well marked mineral, consisting of alumine and silex, with a little magnesia and oxyde of iron. Its texture is lamellar, and it is easily split into thin elastic and transparent plates. It is so soft as readily to yield to the nail, and is found crystalized in four and six-sided prisms. Its usual colours are shades of brown and grey, and sometimes red or black.

Obs. Instead of glass, in some parts of Siberia, mica is employed in windows and lanterns. It has been thus used in Russian ships of war, as it has the advantage of not being shattered, like glass, by discharges of artillery.

Questions for Examination.

1. What do we perceive on the surface of the globe?
2. What are primitive rocks?
3. What transition rocks?
4. What secondary rocks?
5. Describe granite.
6. Also quartz. 7. And felspar. 8. And mica.

SECTION II.

Gneiss, Porphyry, and Horn-blende.

1. Gneiss is composed of the same materials as granite, but is lamellar in its fracture, owing to the large quantity of mica it contains. Granite, on the other hand, is conchoidal in its fracture; or in plain terms, it breaks like the separation of a ball and socket.

2. Mica slate is a compound of mica and quartz,

of a slaty texture, and derives its characters from the quantity of mica it contains.

3. The aspect of a granite district is generally subject to variation, yet it exhibits sufficient traits to be readily recognized by the traveller.

Obs. 1. Granitic rocks are marked by the bold and abrupt precipices which they present to the ocean; and by barren and dreary inland plains, in which blocks of this stone have been indiscriminately scattered. Granite is coarse-grained and is formed in huge blocks, separated from each other by seams, appearing like the ruins of gigantic edifices.

2. In other cases, granite forms irregular and broken peaks, of prodigious height, not split into blocks and masses, as the Alps, the Pyrenees, the mountains of Scotland, the Hartz, and the Tyrol. In Asia and Africa, granite constitutes the Ouralian, Altaian, and Himalayan chains, and the Atlas mountains, extending from Morocco to Egypt: in South America, the lofty ranges of Cordilleras are of a similar description.

3. Granite is one of the most durable productions of nature, resisting for the longest series of ages the destroying hand of time; and for building it is unrivalled. Waterloo Bridge over the Thames at London, is constructed of this material. The ballustrades are of Scottish, their base and coping of Cornish granite; and the fineness of the former to that of the latter is thus strikingly contrasted. Dublin contains noble edifices of granite, procured in the vicinity of that city.

4. Porphyry belongs to the class of unstratified rocks, and has been ranked among the primitive formations. Its constituent is felspar. Genuine porphyry is massive felspar, containing embedded crystals of the same substance; but rocks including distinct crystals of felspar are

called porphyritic, as porphyritic granite, porphyritic trap. This last is of a very dark green colour, approaching to black; and is much employed in the paving of streets, on account of its hardness and durability. The colours of porphyry, which are usually reddish, brown, or green, are derived from metalic oxydes.

Obs. The common aspects of porphyry are those of blocks and masses. It is very durable for building, and was greatly valued among the ancients. The porphyritic districts in Scotland are of singular grandeur; such are Ben Cruachan, on the banks of the Awe, and the terrific precipices of Ben Nevis.

5. Hornblende is a mineral of a dark green colour, consisting of silex and alumine, with magnesia. Granitic rocks frequently contain a large portion of hornblende.

Questions for Examination.

1. Define gneiss. 2. Also mica slate.
3. What traits does a granite district exhibit so as to be known readily?
4. Describe porphyry, also its use and natural appearance.
5. Of what does hornblende consist?

Section III.

Syenites, Serpentine, Talc, Asbestos, and Marble.

1. Syenites. The aspect of syenitic rocks is similar to that of granite and porphyry; the term syenite is derived from Syene, in Upper Egypt, where this rock abounds. It was much used by the Egyptian and Roman sculptors.

Obs. Syenites, or syenitic rocks, may be observed rising from the slaty district of St. David's, in Pembrokeshire; in Cumberland, near Wastdale and Buttermere; in Leicestershire, at Markfield Knowle, a hill in Charawood Forest.

2. Serpentine, another substance belonging to this class of rocks, has for its constituents silex, magnesia, oxyde of iron, and a little carbonate of lime.

The appearance of serpentine is extremely beautiful, and forms a delightful contrast to the sublimity of granitic districts. It derives its name from a variety of tints, such as bright red, green, brown, and yellow. It is prettily traversed by veins of a soft substance called steatite, or soapstone.

Obs. Serpentine, in Cornwall, forms part of the Lizard promontory. It appears in variously shaped and coloured blocks, forming natural arches and caves. This district is of singular interest from a view of the block of porphyry, upon which the serpentine lies incumbent, and the veins of granite associating with those of steatite.

3. Talc resembles mica, but the plates into which it is divisible are not elastic. It consists of nearly equal parts of silex and magnesia, with a little lime; and is found in small tabular crystals; its colours are various shades of green.

4. Schiller-stone, or Schiller-spar, is one of the varieties of *diallage* of the French geologists.

5. Steatite is of different tints, of grey and green, and from its unctuous feel, has been called soap-stone.

6. Asbestos, which is a magnesian fossil was

formerly spun and woven into various kinds of cloth and paper, which when dirty were not washed but thrown into the fire, where they were purified from all kinds of filth. In Venice this art was carried to very great perfection, but it is now lost. In India too, this art was known, and even now the Hindoos use this mineral as a wick for their lamps; this is done on account of its incombustibility, fire having no power over it. Asbestos is found in Scotland, Wales, and many other parts of the world; some of it is like wool, some like flesh, some like cork, and another kind has lately been found in Africa, of a dark blue colour, and much shorter in the fibre than common asbestos.

7. Marble is well known, being very abundant in the secondary rocks; among the primary rocks, it is associated with mica, slate, and serpentine.

Obs. 1. The most esteemed marbles are perfectly white, and susceptible of a fine polish.

2. The isle of Paros, in the Archipelago, furnished that marble from which the finest works of the Grecian artists were sculptured.

3. Scotland furnishes marble of great beauty; that of the isle of Tiree is of a pale red, spotted with green hornblende; Icolmkil possesses a very remarkable quarry of marble. Syenitic rocks constitute the leading feature of this island.

Questions for Examination.

1. Describe syenites.
2. Also serpentine, and the appearance of a serpentine district.
3. Talc.

. Schiller stone.
5. Steatite.
6. Asbestos, and the mode of preparing it for cloth.
7. And marble.

Section IV.

Clay Slate, Limestone, Red Sand-stone, &c.

1. Clay slate, consists of silex, alumine, oxide of iron, with a little lime and magnesia; its colours are shades of grey, and it is so soft as to yield to the finger nail.

Obs. 1. Slate is applied to numerous useful purposes; that which is easily separated into thin plates, is employed for roofing houses; other varieties are used for writing-slates, slate pencils, &c.

Obs. 2. Slate containing embedded matters is called grauwacke, a substance abundant in this country. These embedded substances are usually cubical, resembling pieces of brass.

2. Transition limestones are incumbent upon clay slate, and are distinguished from primitive limestone, or statuary marble, by a less decidedly crystalline texture. Lying directly upon slate, this rock contains few organic remains; but where red sand-stone is interposed, organization appears more frequent, being the remains of corals and zoophytes.

Obs. 1. Mountain lime-stone is an excellent material for building, aud sufficiently hard to receive a good polish, for ornamental purposes.

Obs. 2. The black variety, known by the name of lucullite, or black marble, is often tastefully manufactured. It is found in Derbyshire, Sutherlandshire, and Galloway.

Obs. 3. All these limestones are converted into a more or

less pure quick-lime, by a red heat, and they are then valuable for manures, and mortar.

3. Argillaceous iron-stone is found both in layers and nodules, in coal formations.

Obs. This is a poor ore of iron, seldom yielding more than 30 per cent of metal. But from its association with coal and limestone, it is of much importance, being the main source of enormous quantities of iron manufactured in this country.

4. Red sand-stone consists of silex, oxide of iron, alumine, and more or less lime. It frequently rests upon slate, and from its position has acquired the term of old red sand-stone; its beds are of great thickness. It is much used in building, but moulders through the action of air and moisture.

Obs. Red sand-stone is very abundant in England, and its surface is generally favourable to vegetation, and Hawthornden, near Edinburgh abounds with this stone; and of it the ancient castle is constructed.

Slates, grauwackes, and limestones, are the principal seats of the metallic ores.

Questions for Examination.

1. Describe clay-slate, and state its uses.
2. Lime-stone, and its uses.
3. Transition lime-stone, and its uses.
4. Mountain lime-stone, and its uses.
5. Argillaceous iron-stone, and its uses.
6. Red sand-stone, and its uses.

SECTION V.

1. *Greenstone, Basalt, Amygdaloid, and Toadstone,*

ARE distinguished into primary, transition, and floetz Traprocks, or Whinstones.

1. Greenstone is a compound of horneblend and felspar.

2. Basalt abounds in black oxide of iron.

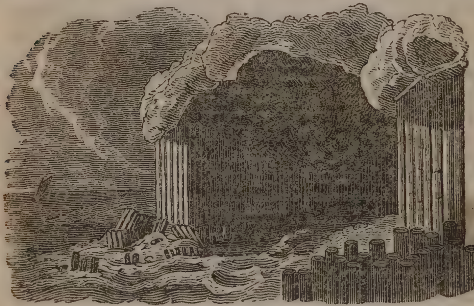
Obs. 1. Greenstone is met with in many parts of England immediately upon granite and primary rocks, breaking into large blocks of irregular forms. A piece of basalt, presented to a common observer, would be pronounced the product of a volcano, the similarity between it and lava being very great.

Obs. 2. Upon the coast of Antrim, in Ireland, massive and columnar basalt is seen in all its varieties; the former abounding in deep caverns, the latter presenting lofty façades to the ocean. The Giant's causeway, esteemed one of the greatest curiosities in the world, consists of three piers of basalt columns, extending some hundred feet into the sea. This causeway is surrounded by precipitous rocks, from 200 to 400 feet high, in which are several striking assemblages of columns. Some of these are vertical, some inclined and horizontal, but all are, as it were, morticed or driven into each other. On this coast Pleskin presents colonnades of great height and regularity, separated from each other by tabular basalt. Fairhead, the north-east cape of Ireland, is a range of columns, of from 10 to 20 feet diameter, and between 200 and 300 feet high. These are supported upon a steep declivity, and offer to the mariner the spectacle of a terrace, towering nearly 600 feet above the waves.

Obs. 3. Another Basalt district, exceeding the former in magnificence, presents itself in sailing down Loch Nagaul, in the Island of Mull. The coast exhibits the step-like appearance of basaltic rocks; the fine columns alternating with yawning caverns.

The isles of Ulva and Gometra, two of the Hebrides, rise with the abrupt and irregular precipices common to this formation. The Treshamish Isles belonging to the same Archipelago, exhibit columnar and massive basalts, and in the midst of this grand panorama, Staffa presents itself.

The columns, which are from 60 to 90 feet high, are approached by a fine causeway, rising gently from the deep, and an immense weight of tabular basalt appears supported by them. The pillars are perpendicular, inclined, and in some places curved. In Fingal's Cave, of which the annexed figure is a very correct picture, the ranges extend, in deep perspective, into the interior of the rock; presenting a scene of such unrivalled grandeur, as hitherto has defied the descriptive pen of the poet, or the pencil of the painter.



Questions for Examination.

1. How are Greenstone, Basalt, Amygdaloid, and Toadstone distinguished.
2. In what respects do greenstone and basalt differ?
3. Describe the basalt districts of Ireland.
4. Describe those of Scotland.

Section VI.

Gypsum, Fluor Spar, Ponderous Spar, Common Salt, and Coal.

1. Gypsum, or sulphate of lime, known also

by the name of plaster-stone, selenite, and alabaster, occurs in great plenty in many parts of the red strata.

Obs. When the common gypsum has been heated to redness, it loses its water, and falls into a powder, which, when ground fine, is termed Plaster of Paris.

2. *Fluor Spar.*

Fluate of Lime or Derbyshire Spar, is a mineral much used in the formation of Vases, &c.

Obs. It is richly veined, and takes a beautiful polish.

Obs. 2. The Petrifaction of vegetables, &c., is owing to their immersion in water, impregnated by the salts of lime, &c. The Petrifaction proceeds by an absorption or destruction of the vegetable matter, and a deposition of Carbonate of lime, &c.

3. *Muriate of Barytes, or Ponderous Spar,*

Is a plentiful mineral, and of greater weight than any other.

Obs. It is highly poisonous.

4. *Common Salt, or Muriate of Soda,*

Is found in immense beds in the red sand-stone of Cheshire. Near Middlewich, Northwich, and Nantwich, it is accompanied by gypsum. It begins about 90 feet below the surface, and is 75 feet thick: under this, and separated from it by about 30 feet of hardened clay, is another bed of salt, the extent of which is unknown.

Obs. The Mines of Cracow in Poland are so extensive,

as to be capable of furnishing the whole world with salt for 8000 years. But these mines are actually small in comparison with some in the United States of America.

5. Coal is the most important product of the middle strata.

What is called a coal-field, district, or coal-basin, may be regarded as a concavity, varying in extent, from a few, to many miles, and containing numerous strata of various thickness, alternating with sand stone-clays, and soft slate or shale. The latter contain impressions of vegetable matters, and the remains of shell fish.

Obs. The deepest English coal mines are in the counties of Durham and Northumberland, and the thickest beds in Staffordshire; the most productive varying from six to nine feet.

And as far as the economical application of coal is concerned, may be reduced to two classes.

1st. The coals of Lancashire, Scotland, and the west of England, burn quickly leaving a light ash.

2ndly. The coals of Northumberland and Durham become soft and puffy, spout out bright jets of flame; require poking to continue in combustion, and produce bulky cinders.

The greater number of geologists are now unanimous, that coal is of vegetable origin.

Questions for Examination.

1. Define gypsum, and state its use.
2. Define fluor spar, and state how the petrifaction of vegetables is effected.
3. Define ponderous spar.
4. Where is salt found?
5. Describe a coal field. What varieties of coal are there?

Section VII.

Volcanic Hills.

Mount Vesuvius in Italy, Etna in Sicily, Hecla in Iceland, and Xurullo in South America, are volcanic hills of greatest note for their terrific, picturesque, and destructive effects.

These hills are conical, and serve to give some idea of the vast powers of subterranean agents. The diagram at the head of this article represents the volcanic district of Jurullo in South America.

Obs. In June, 1811, a volcano was discovered in the sea off St. Michael, and it formed an island about a mile in circumference. The captain of an English vessel planted the standard of his nation upon it; but in a few months, it sunk; He had named it, "The Island of Sabrina."

2. Until lately, the cause of volcanic fire was referred to sulphur, coal, and other inflammable matter, supposed to be burning in immense masses in the bowels of the earth, but the products of

volcanic irruptions by no means agree with such an explanation.

Earthy alkaline, and metallic bodies, form the lava, and as the products of combustion always have a reference to the combustible, such matters were not likely to be produced from sulphur and coal.

3. We have only to suppose the access of water to large masses of different metals, and that it is decomposed by a galvanic action as exemplified in experiments where copper and zinc are used in voltaic batteries. By these means, immense volumes of Hydrogen Gas are let free as the metals are oxidised. The violence of the action sets fire to the hydrogen, and the accumulated heat is so intense as to cause the fusion of every surrounding substance.

By this theory, we are in possession of all the knowledge that is wanted to produce the tremendous effects of earthquakes and volcanoes:—for what power can resist the expansive force of steam? What power can resist the sudden evolution of gaseous fluid, accompanied by torrents of the earth in a state of fusion, which such a concurrence of circumstances must give rise to, and which are the actual concomitants of volcanic irruptions?

Questions for Examination.

1. Describe the form of volcanic hills.
2. To what cause was volcanic fires referred, until lately.
3. How are volcanoes really produced?

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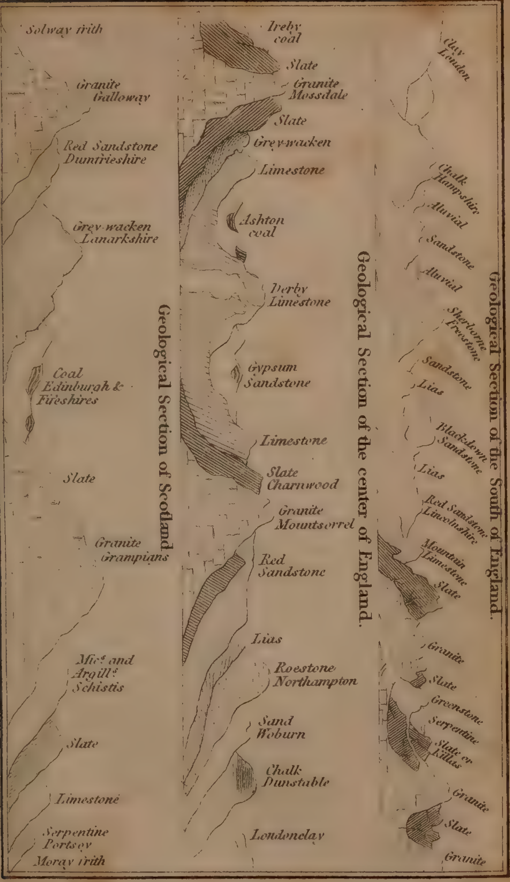


Engraved for Pinnock & Maunders Elements of Nat.& Ex. Phil. by Sid^y Hall.

CHAPTER V.

MECHANICAL PHILOSOPHY.

Introduction.

1. The SCIENCE of MECHANICS treats of the laws, the equilibrium, and the motion of solid bodies :—of the forces with which bodies may be made to act upon one another ; and of the means by which these may be increased.

Obs. This science depends upon very simple principles, and may be resolved into the power which *gravity* and the *laws of motion* have upon MATTER.

SECTION I.

Of the general Properties of Matter.

2. We may in general define MATTER to be every substance or being that acts upon our senses, either immediately, or by the perceptible effects which it produces upon our bodies.

Illus. 1. Some sorts of matter are visible, or capable of being seen, as *wood*, *stone*, &c. We see them because they permit not the rays of light to pass through them ; but reflect those rays to our eyes upon the retina of which they are painted.

2. Matter that is transparent is always invisible ; and its existence is only ascertained from its effects upon other bodies. The air of the atmosphere is of this nature.—

Though perfectly invisible, when dry and pure, it is nevertheless a substance or matter.

3. All matter has the properties of SOLIDITY or *impenatrability*, of DIVISIBILITY, MOBILITY, and INERTIA.

4. SOLIDITY is that property by which *two bodies* cannot occupy the *same place* at the *same time*.

Illus. If a piece of wood, or a stone, occupy a certain space, before you can put another body in that space, you must first remove the stone or wood; and though fluids do not appear at first to offer such resistance, yet in proper circumstances, they retain this property in an equal degree. We may prove this by

Experiment. Put some water into a tube, closed at one end, and insert into it a piston, or a piece of wood or metal, that perfectly fits the inside; you will find it impossible, by any pressure to get the piston to the bottom without breaking the tube.

If you try the same experiment with the tube empty, as it is called, but in reality filled with air, you will find the same impossibility of pushing the piston to the furthest end of the tube.

Hence, both water and air, and every other fluid, is equally impenetrable, in this sense of the word, with a piece of marble or steel.

Obs. In common language, by solidity or impenetrability is understood, the property of not being easily separated into parts.

5. DIVISIBILITY—that property by which matter is capable of being separated into parts, which may be removed from each other, may be illustrated in the following manner:

Illus. In bodies of sensible magnitude, this divisibility is very obvious; for we can divide them into 2, 10, and 100 parts; nor by subdividing, can we ever arrive at a part

so small, but we can conceive that it consists of two halves.

Examples. 1. If a grain of gold be melted with a pound or 5760 grains of silver, and if a single grain of the mass be dissolved into diluted nitric acid, the gold which is only the 5761st part of a grain, will fall to the bottom and be visible, but the silver will be dissolved in the acid.

2. And a *grain* of gold may be hammered until it is the 30 thousandth part of a line in thickness, when it will cover 50 square inches. Each of these square inches may be divided into 200 strips, each strip into 200 parts, each of which may be seen by the naked eye. Consequently, a square inch contains 40,000 visible parts. These 40,000 $\times$50, the number of square inches, give 2,000,000 of parts, every one of which you may see by the naked eye.

3. The melt of a cod-fish contains animalculæ so small, that many thousands of them may stand on the point of a needle.

4. The natural divisions of matter are still more wonderful. In odoriferous bodies, a surprising subtilty of parts is perceived. And the particles of light are still more minute. So that matter is actually divisible to a greater degree than our senses can extend in conveying a conception of its divisibility. In fact, matter cannot be annihilated by division; therefore, even in imagination, we cannot conceive any particle so small, as will not have an upper and an under surface.

6. Mobility is that property of matter, by which it is capable of being moved from one part of space to another.

Obs. Both experiment and observation prove that all matter is capable of being moved, if sufficient force can be applied for that purpose.

7. Inertia, or *Inactivity*, is the property which bodies have to remain in the same state into which they are put, whether of rest, or of motion, unless prevented by some external force.

Illus. Since matter begins not of itself to move, unless it be acted upon in some way, when, therefore, we see bodies that have been put in motion, falling into a state of rest, we are to attribute the decay of motion to the resistance of the air, or to friction. For if these could be entirely removed, the body would continue in motion for ever.

Examples. 1. A marble shot gently from the fore-finger and thumb, runs but a small distance on a carpet; its motion would be longer continued on fine smooth ice. In this case, the friction is greater on the carpet, and less on the ice; but were there no friction, nor any resistance of the air, the marble once put in motion, would continue to revolve, till it traversed the entire length of the carpet or ice.

Questions on the foregoing Articles.

1. Of what does the Science of Mechanics treat, and on what principles does it depend?

2. Define matter and its two properties of visibility and invisibility?

3. What are the general properties of matter?

4. Define solidity. Illustrate your definition, and prove your illustration by experiments, with a tube and piston.

5. Define divisibility; and illustrate your definition, 1st. from an admixture of gold and silver diluted in nitric-acid; 2nd. a grain of gold hammered and divided into 2,000,000 of parts; 5th. from the melt of a codfish; and lastly, from the natural divisions of matter, as from odoriferous bodies.

6. Define mobility.

7. Define inertia; and illustrate how matter begins motion; what the effect is of friction on a marble in motion.

Section II

Of Motion and its Laws.

1. Motion is a simple idea, and cannot therefore be easily defined, without using a circumlo-

cution. We describe it by its sensible effects, when we say, *motion is a continual and successive change of place.*

2. There are two sorts of motion, with which we are principally acquainted : one is the motion by which an entire body is transferred from one place to another ; as that of a stone falling, or of a ship sailing :—another kind of motion not less common nor unimportant, is the motion of bodies among themselves ; as, the imperceptible motion by which plants and animals grow.

The Laws of Motion.

3. Every CHANGE which we observe in the condition of things, is considered as an *effect* indicating the *agency*, characterizing the *kind*, and measuring the degree of its *cause*. And in mechanics, the cause of any change of motion is called a moving or changing *force*.

Obs. Whenever, therefore, we use the word *force* or *power* in mechanics, it is to denote *that* which causes a change in the state of a body, whether that state be rest or motion.

4. Every body *perseveres* in a state of rest, or uniform rectilineal motion, unless affected by some moving force.

5. Every *change of motion* is always proportionate to the degree of the moving force by which it is produced, and it is made in the line of direction in which that force is impressed.

6. *Action* and *re-action* are always equal and

contrary: that is to say, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

7. In considering motion Newton attends:—

1. To the *force* which impresses the motion;
2. To the quantity of matter in the body moved;
3 To the velocity and direction of motion;
4. To the space passed over by the moving body;
5. To the time employed in going over that space;
6. To the force with which one body strikes another opposed to it.

8. To put a body in motion, there must be a *sufficient cause* or MOTIVE POWER. Motive powers are either *muscular*, or *mechanical;* as the *action of men* and other *animals;* the *force of wind*, *gravity*, the *pressure of the atmosphere*, the *elasticity of fluids*, *springs*, *as those of watches*, *steam*, &c.

9. The *velocity of motion* is estimated by the time occupied in moving over a certain space, or by the space moved over in a certain time. Thus you can conceive, that if in a short time, you move over a great space, the greater is the velocity with which you moved; and on the contrary, the greater the time you take to walk over a field, and the less the field is, the less is the velocity: to ascertain the degree of velocity, the space run over must be divided by the time; but to measure the space run over, the velocity must be multiplied by the time.

Examples. 1. If a body moves over 1,000 yards in 10 minutes, its velocity will be 100 yards in the minute. If A and B be two bodies, whose velocities we would com-

pare, and we know that A moves over 54 yards in 9 minutes, and B 96 yards in 6 minutes, the velocity of A will be to that of B in the proportion of 6 to 16. For $54 \div 9 = 6$; and $96 \div 6 = 16$.

2. If A and B set out on a journey, and A walks 2 miles and a half, while B walks 5 miles in an hour; the velocity of B will be double that of A; for $2\frac{1}{2} \times 2\frac{1}{2} = 5$.

3. If a horse run one mile in 4 minutes, he will run 15 miles in an hour; for $15 \times 4 = 60$ minutes. And if A walks one mile in 12 minutes, he will walk 5 miles in an hour; for $12 \times 5 = 60$.

Questions for Examination.

1. Define motion.
2. With how many sorts of motion are we acquainted?
3. What is every change we observe in the condition of things to be considered? And what is a moving or changing force?
4. In what state does every body persevere?
5. To what is every change of motion proportional?
6. What is meant by the equality and contrariety of action and re-action?
7. What six circumstances must we attend to, in considering motion?
8. What are motive powers?
9. Describe the method of estimating the velocity of motion: and give me examples to illustrate your definition.

Section III.

Of Simple and Compound Motion.

1. *A body in motion* must every instant tend to some *particular point*. It may always tend to the same point, in which case the motion will be in a *straight line*. Or it may be continually changing the point to which its motion is directed,

and this continual change of the point will produce a *curvilinear motion.*

2. In mechanics, we use the term *equable motion,* which is either *simple* or *compound.*

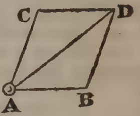
Illus. 1. SIMPLE MOTION is that produced by the action or impressed force of *one cause;* as the motion of a boat in smooth water, which a man draws with a rope.

2. COMPOUND MOTION is that which is produced by two or more conspiring powers, that is to say, by powers, the directions of which are neither opposite nor coincident.

3. If two or more forces differently directed, act upon the *same* body, at the *same time,* as the body in question cannot obey them all, it will move in a direction somewhere *between* them.

Obs. This is called the *composition* and resolution of forces or of motion, and may be illustrated in the following manner:—

Example of Compound Motion.



Illus. 1. Suppose a body A to be acted upon by a force in the direction A B, while at the same time it is impelled by another force in the direction A C, it will then move in the direction A D; and if the lines A B, A C, be made of lengths proportionate to the forces, and the lines C D, D B, be drawn parallel to them, so as to complete the parallelogram A B D C, then the line which the body A will describe, will be the diagonal A D; and the length of this line will represent the force with which the body will move.

But if the body be impelled by equal forces acting at right angles to each other, it will move in the diagonal of a square.

Obs. Instances in nature, of motion produced by several

powers acting at the same time, are innumerable. A ship impelled by the wind and tide is one well known; a paper kite, acted upon in one direction by the wind and in another by the string, is another instance.

SECTION IV.

Of Accelerated and Retarded Motion.

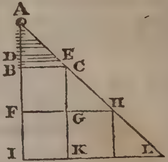
4. ACCELERATED *motion* is that in which the velocity is continually increasing, from the continued action of the motive power. And *uniformly accelerated motion* is that in which the velocity increases equally in equal times.

5. RETARDED *motion* is that in which the velocity is continually decreasing. And in *uniformly retarded* motion, the velocity decreases equally in equal times.

Obs. The regularly increasing velocity with which a body falls to the earth is an instance of accelerated motion that is caused by the constant action of gravity. And the regularly decreasing velocity of a marble on a level surface is an instance of retarded motion, caused by the action of friction and the resistance of the atmosphere.

6. The VELOCITIES of falling bodies are in proportion to the spaces run over; and the space passed over in each instant increases in arithmetical progression, as the numbers 1, 3, 5, 7, 9, &c.; and their RETARDATION by gravity and the resistance of the air, is represented by the numbers 10, 9, 8, 7, 6, &c.

Example of Accelerated Motion.



1. Let us suppose that in the △ A B C, the time which a body takes to fall, is expressed by A B and the velocity acquired at the end of the fall by B C; if we divide A B into a number of equal parts, indefinitely small, and from each of these divisions suppose lines, as D E drawn parallel to B C, each of those lines will express the velocity of the falling body in the several respective points of time, each greater than the former by a certain quantity of increase which follows from the nature of the triangle.

Now the spaces described in the same time are proportional to the velocities; and the sum of the spaces described in all the small portions of time, is the space described from the beginning of the fall. But the sum of all the lines parallel to B C taken indefinitely near to each other, constitutes the area of the △. Therefore, the space described by a falling body, in the time expressed by A B, with an uniformly accelerated velocity, of which the last degree is expressed by B C, will be represented by the area of the triangle A B C.

2. Let us now suppose that gravity ceased to act, and that the body moved during another portion of time, B F=A B, with the acquired velocity represented by B C.

As the space moved over is found by multiplying the velocity by the time, the rectangle B C G F will represent the space moved over in this second portion of time, which is twice the △ A B C; and, in consequence of the accelerating velocity, twice the space moved over in the same time.

But if we suppose gravity still to act, besides the space B C G F, which it would have moved over by its supposed velocity, we must add the △ C G H for the effect of the constant action of gravity; therefore, in this second portion of time, the body moves over three times the space which it did in the first portion.

3 In like manner it may be easily seen from the diagram, that in the next portion of time, the body would move over five times the space; in the next, seven times, and so on in arithmetical progression.

Hence the space run over is as the square of the time: that is to say, in twice the time a body will fall through four times the space; in thrice the time, through nine times the space, &c. Since the triangle C G H = the triangle A B C, and the rectangle B F G C = twice the triangle A B C, the whole triangle A F H is evidently equal to four times the triangle A B C.

Obs. 1. In falling a body moves at the rate of $16\frac{1}{12}$ feet in the first second, and acquires a velocity of twice that, or $32\frac{1}{6}$ feet in a second. At the end of the next second, therefore, it will fall $64\frac{1}{3}$ feet, the space being as the square of the time: but the square of 2 is 4, and 4 times $16\frac{1}{12}$ is $64\frac{1}{3}$. Hence by the same rule, you find that in the third second it will fall $144\frac{3}{4}$ feet, in the fourth second $257\frac{1}{3}$, and so on.

It is to be understood, however, that by this velocity is meant what bodies would acquire were they to fall through a space free of air, for its resistance considerably diminishes their velocity in falling.

Of the Momentum of Bodies.

7. The *force* with which a body moves, or which it would exert upon another body opposed to it, is always in proportion to its velocity, multiplied by its weight or quantity of matter; and this *force* is called the MOMENTUM of the body.

Let the pupil substitute the word MOMENTUM for *hard*, and VELOCITY for *fast*, and he will at once understand the principle of mechanics now before him. The *momentum* of a marble shot from the hand is in proportion to its *velocity;* the same marble will hit twice as *hard*

if it move twice as *fast*, or *ten times* as hard if it move *ten times* as fast.

Of Space and Time.

8. SPACE has no limits or bounds. It consists however, of parts into which the mind divides it; but those parts are not capable of actual separation from each other.

Obs. 1. Space affords no resistance to bodies moving through it. Being perfectly uniform in all its parts, it is impossible to distinguish them from each other, but by bodies placed in them.

2. SPACE is either *absolute* or *relative;* ABSOLUTE SPACE is mere extension; it has no limits or bounds, and is itself immoveable: RELATIVE SPACE is that part of absolute space, which is occupied by any body that is compared with any other part occupied by another body.

9. The consideration of *matter* leads to the consideration of *space;* the consideration of MOTION necessarily involves that of TIME; for no motion can be instantaneous.

Illus. TIME is either *absolute* or *relative.* ABSOLUTE TIME is a portion of duration, whose quantity we know only by comparison with another portion. The relation, therefore, between any two parts of absolute time is not to be discovered. RELATIVE TIME is a part of duration which elapses during any motion of a body, or any succession of internal appearances.

Obs. 1. There is a striking analogy between the properties of space and time: hence, TIME is represented by *lines* and measured by *motions;* hence also we call an *instant* the boundary between any two contiguous portions of time, as a point is the boundary of any contiguous lines.

2. To render time susceptible of mathematical discussion, it must be conceived as measurable; and to this end, it is

necessary to recur to some event which we imagine uniformly requires equal times for its accomplishment.

3. We are furnished with such an event in the complete rotation of the earth upon its axis, which marks out a natural day as an apt and obvious *unit* of time.

4. A *natural day* considered as an unit of time is divided into twenty-four hours; each hour into sixty minutes; each minute into sixty seconds. And these equal parts or divisions are consulted in machanics as well as in the ordinary affairs of life.

5. Every one knows that a *moment* is any small portion of time.

Questions for Examination.

1. How does a body in motion always tend? and whence do rectilineal and curvilinear motions derive their origin?

2. Into what kinds is equable motion divided? Define also simple and compound motion.

3. What is that which has obtained the name of the composition and resolution of forces or motion? And prove to me how a body acted upon by forces differently directed, moves in the diagonal of those forces.

5. Define accelerated and retarded motion; also uniformly accelerated or retarded motion.

6. What is the proportion of the velocity of a falling body to the space run over? And what is the progression of increase and of retardation.

7. Define and illustrate the momentum of a body.

8. Illustrate space; absolute and relative.

9. Also time, absolute and relative; and then what analogy space has to time.

SECTION V.

Of Attraction and Repulsion.

1. ATTRACTION is the tendency which all bodies have to approach each other. In Mechanics,

attraction is of two kinds, the *attraction of cohesion*, and the *attraction of gravitation.*

2. The ATTRACTION OF COHESION takes place between bodies, only when they are at very small distances from each other. By this attraction, possessed by the minute parts of matter, bodies preserve their form, and are prevented from falling to pieces.

Example. To prove the attraction of cohesion, take two pieces of lead with flat surfaces; scrape them clean with a knife, squeeze them together and they will adhere so firmly as to be separated with difficulty. And if you wet two bits of glass with water, they also will adhere firmly. Two globules of quicksilver placed near each other, will run together, and become one drop or ball.

A Table of cohesive Powers of different Solids.

3. To estimate the absolute cohesion of solid bodies, Professor Musschenbrook, applied weights to separate them according to their length.

The pieces of wood he used were parallelopipedons, whose side was $\frac{27}{100}$ths of an inch. The metal wires used were $\frac{1}{10}$th of a Rhinland inch in diameter. They were drawn asunder by the following weights.

	lbs.		*lbs.*
Fir	100	Copper	299¼
Elm	950	Brass	360
Alder	1000	Gold	500
Oak	1150	Iron	450
Beech	1250	Silver	370
Ash	1250	Tin	49¼
Lead	29¼		

4. CAPILLARY ATTRACTION is accounted a species of cohesion. It is called capillary, from the tubes which draw the water above its level,

being small as hairs. And the suspension of fluids in capillary tubes is owing to the attraction of the ring contiguous to the upper surface of the fluid. The height to which the fluid rises is inversely as the diameter of the bore.

Exper. 1. Take a small glass tube open at both ends, dip it in water, and the water will rise in the tube higher than its level in the basin: the water will rise the higher, the smaller the bore of the tube is.

2. Take two pieces of glass, five or six inches square, join any two of their sides, separate the opposite sides with a small piece of wood, so that the surface may form a small opening, and immerse them about an inch deep in a basin of coloured water: then the water will rise between the glasses and form a very beautiful curve.

3. Upon the same principle it is that a piece of sugar, or a sponge, draws up water or any other fluid.

5. All vegetables are but bundles of capillary tubes; and whether we consider earth, water, salt and oil, as the food of plants, that food must be formed by water into an emulsion, capable of being acted upon by capillary attraction; unless we suppose the juice, or food, to rise in those tubes by some law of hydraulics.

As all the roots are but assemblages of these tubes, there can be little doubt but their attraction supplies the plant, or tree with its first food; though other causes, no doubt, assist in carrying it to the tops of the tallest trees, such as dilatation and contraction, by the successive heat and cold of day and night; the muscular action of vascular rings round the tubes, irritated to contraction by the stimulant sap, &c. The interior bark conducts the nourishment supplied by the earth. Leaves on *one side* draw nutrition

also from the air, and perspire on the other; light probably does the rest.

6. It is probably owing to the various degrees of cohesion, that some bodies are hard and others soft; that some are in a solid, others in a fluid state. For when attraction prevails in bodies they become *solid;* when fire prevails they become gas; hence fluidity seems a medium between both.

Obs. 1. As it is by the attraction of cohesion that the parts of bodies are kept together, this attraction is overcome when a body is broken. Hence the reason of soldering metals, glueing wood, &c Hence, also, when the particles or moleculæ, of which a body is composed, so adhere the one to the other, that they cannot be separated without effort, we say of such a body that it is *solid;*—such are metals, stone, wood, &c. Hence, also, such substances as are composed of particles adhering very slightly, and which, yielding to any small effort, are easily moved among each other, we term *fluids,* such as water, beer, air, &c.

2. These properties may result from the different figures of the particles, and the greater or less degree of attraction thereupon.

7. Elasticity may arise from the particles of a body, when distended, not been amply drawn into each other's attraction; as soon therefore as the force which acts upon it ceases, they restore themselves to their former position.

8. Density, strictly speaking, denotes the closeness of particles, and we use the word here as a term of comparison, expressing the proportion or quantity of matter in one body, to the quantity in another.

Obs. Density, therefore, is directly as the quantity of matter, and inversely as the magnitude of the body.

9. Repulsion is a force supposed to extend to a small distance round bodies, and prevent them from coming into actual contact.

Obs. The repelling force of the particles of a fluid is small, and, therefore, if a fluid be divided, it readily unites again. But, if a hard substance be broken, the parts cannot be made to adhere, unless they be moistened or melted according to their nature.

Examples. 1. Water repels most bodies till they are wet. A small sewing needle will swim in a basin of water.

2. Drops of water will roll on the leaves of many vegetables without wetting them.

3. If a ball of light wood be dipped in oil, and afterwards dropped into water, the water will be repelled from the wood, and will form a channel round it.

Questions for Examination.

1. What is *attraction;* and of how many kinds, in mechanics?

2. Describe how the attraction of cohesion takes place—what the sphere of repulsion round bodies is—and prove from experiments with lead, glass and quicksilver how this attraction takes place.

3. How are the cohesive powers of different solids estimated by Musschenbrook?

4. What is capillary attraction? Now give me experiments to prove your definition?

5. Describe how all vegetables are but bundles of capillary tubes; and of what use to plants and trees the assemblages of these tubes in their roots are.

6. To what are the solidity and fluidity of various bodies owing? And how is the attraction of cohesion overcome?

7, 8. Define elasticity and density.

9. Define repulsion, and shew me how water repels most bodies till they are wet; and how oil repels water.

SECTION VI.

The Attraction of Gravitation.

1. Gravity is that force by which all the masses of matter tend towards each other, and which they exert at all distances. It is by this attraction that heavenly bodies are retained in their several places, by their action on each other; and it is also by this that a stone dropped from a height falls to the surface of the earth.

2. It is one of the laws of nature that every particle of matter gravitates towards every other particle. The planets and comets all gravitate towards the sun, and towards each other, as well as the sun towards them, and that in proportion to the quantity of matter in each.

3. All terrestrial bodies tend towards the centre of the earth, consequently bodies fall every where perpendicular to its surface, and on opposite sides in opposite directions. As gravity acts upon all bodies in proportion to their quantities of matter, it is this attractive force that constitutes their weight.

4. In all places equi-distant from the centre of the globe, the force of gravity is equal. The force of gravity is greatest at the earth's surface, from whence it decreases both upwards and downwards. Upwards the force decreases as the square of the distance from the centre increases; but below the surface of the earth the force of gravity decreases, so that at the distance of half a semi-diameter from the centre, it is but half what it is at the surface; at one-third of the semi-diameter one-third, and so on for any other assumed distances.

Gravity and weight are, in particular circumstances, synonymous terms. We say such a piece of lead weighs a pound, but if by any means it could be carried 4000 miles above the surface of the earth, it would only weigh four ounces; and provided it could be removed 8000

miles above the earth, which is three times the distance from the centre that the surface is, it would weigh only one-ninth of a pound.

Again, since the force of gravity downwards decreases, as the distance from the surface increases, 16 ounces would weigh, at one-half the distance from the centre to the surface, only eight ounces, and so on for one-third, &c.

Hence a piece of metal &c. weighing on the surface of the earth, one pound will

At the centre weigh	- - - - - - - - - -	0
1,000 miles from the centre	- - -	$\frac{1}{4}$ of a pound.
2,000	- - - - - - - - - - - - - - - -	$\frac{1}{2}$
3,000	- - - - - - - - - - - - - - - -	$\frac{3}{4}$
4,000	- - - - - - - - - - - - - - - -	1
8,000	- - - - - - - - - - - - - - - -	$\frac{1}{4}$
12,000	- - - - - - - - - - - - - - - -	$\frac{1}{9}$

Questions for Examination.

1. What is the attraction of *gravitation?*
2. What is one of the laws of nature? And to what do all terrestrial bodies tend?
3. How have all bodies whatever some degree of gravity and weight?
4. And now illustrate the force of gravity at places equidistant from the centre of the globe, at the earth's surface, and at the respective heights of 1,000, 2,000, 3,000, 4,000, 8,000 and 12,000 miles.

SECTION VII.

Of Central Forces.

1. From the inability of all matter to move itself, all motion produced by one force only acting upon a body must be rectilinear; for it must receive some particular direction from the power that impressed it, and must retain that direction until it is changed by some other power.

Whenever, therefore, we see a body moving in a

curvilinear direction, we may be certain that it is acted upon by two forces at least; but when one of those two forces ceases to act, the body will move again in a straight line.

Example. Thus a stone in a sling is moved round by the hand, while it is pulled towards the centre of the circle which it describes by the string; but when the string is let go, the stone flies off in a tangent to the circle, which the revolution of the string described.

2. The tendency which every body has to fly off from its centre is called the *centrifugal force*: the force by which bodies are drawn to a centre is called the *centripetal force*.

Obs. These two forces are called together *central forces*, and their combined action upon a body in motion compels the body to revolve in a curve. These are the doctrines of the immortal Newton, who overthrew the hypothesis of Descartes, that, from mere matter and a certain quantity of motion given it at first, attempted to account for all the phenomena of the material world.

Questions for Examination.

1. Define and illustrate rectilinear motion.
2. Also what is meant by centrifugal force; and what thence by central forces.

Section VIII.

Of the Centre of Gravity.

The centre of gravity of a body, or of a system of bodies, is that point about which all the points of the body or system of bodies, do in any situation exactly balance each other.

Hence, if a body be suspended or supported by this point, it will rest in any position into which it is put. Also, whatever supports that point, bears the weight of the whole body; and while it is supported, the body cannot

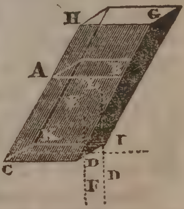
fall. We may, therefore, consider the whole weight of a body as centered in this point, which we call the centre of gravity of the body, as the sun is the centre of gravity of the solar system.

2. The common centre of gravity of two or more bodies, as you see by the annexed figure, is the point about which they would equiponderate, or rest in any position.

Illus. If the centres of gravity of two or more bodies, A and B, be connected by the right line A B, the distances A C and B C, from the common centre of gravity C, are reciprocally as the weights of the bodies A and B; that is, A C : B C :: B : A.

3. If a line be drawn from the centre of gravity of a body perpendicular to the horizon, it is called the *line of direction*, because it is the line that the centre of gravity would describe if the body fell freely. This is illustrated from the diagram we have here annexed.

Obs. It is the property of this line, that while it falls *within* the base upon which the body stands, the body cannot fall, but if it fall *without* the base, the body will tumble.



Illus. Thus, in the inclining body A B D C, the centre of gravity is E, and the body stands firmly on its base, C D I K, because the line of direction E F falls within the base.

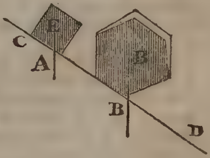
But if the weight, as A B G H, be laid upon the top of the body, the centre of gravity is raised to L; and then, as the line of direction L D falls without the base at D, the centre of gravity (L) is not supported, and the body and weight will tumble.

Corol. Hence is obvious the danger of rising hastily in a coach or boat, when it is likely to overset. By so doing, the center of gravity is liable to be thrown out of the base, and the vehicle or boat overset. The proper conduct of passengers in such circumstances is to lie down in the bottom, and bring the line of direction, and consequently the centre of gravity within the base. Coaches are now built so as to confine the centre of gravity within the base upon the most uneaven roads.

4. The *broader* the base, and the nearer the line of direction is to its centre, the more firmly the body stands. On the contrary, the *narrower* the base, and the nearer the line of direction is to its side, the more easily may the body be overthrown. And in these propositions the characters of the new patent coaches and those of the old high built vehicles are well contrasted.

And hence the ease with which a sphere is rolled upon a horizontal plane; and the difficulty, if not impossibility, of making things which are sharp pointed stand upright on the point.

5. If a plane, C D, be inclined, on which a heavy body, E or B, is placed, the body will slide down upon the plane, while the line of direction falls within the base, as E in the cube:



but it will roll down when that line falls without the base, as B B, in the pentagon.

Thus the body E having the line of direction E A within the base of the cube, will only slide down the inclined plane C D; but the line of direction B B, of the pentagon B, falling out of the base, that body will roll down the plane.

Questions for Examination.

1. What is the centre of gravity of a body or system of bodies.

2. Illustrate the doctrines of the common centre of gravity of two or more bodies.

3. Describe the *line of direction,* and illustrate the properties of this line when it falls within or without the base of a body.

4. Illustrate further how a body stands firmly, or may be the more easily overthrown.

5. Describe the conduct of a body on an inclined plane, when the line of direction falls *within* or *without* the base.

SECTION IX.

The Mechanical Motions of Animals.

1. If we consider attentively the various motions of animals, we shall find them regulated consistently with the principles of the foregoing Section.

When the line of direction falls within the base of our feet, we stand, and most firmly, when it is in the middle of the body, as A, in the human figure in the next page; but when it is out of the base we immediately fall.

When you endeavour to rise from a seat, you thrust forward your body, and draw your feet backward, till the vertical line from the centre of gravity falls just before your feet; this enables you to rise, and prevents you falling forward; you advance one of your feet, till the vertical line of direction is brought between your feet, in consequence of which you may stand firmly.

2. When a man, B C, as shewn in the diagram, endeavours to walk, he first extends his hindermost leg and foot, S, almost to a straight line, and at the same time bends a little the knee, H, of his fore leg. Thus his hind leg is lengthened, and his fore leg shortened, and by this means his body is moved forward, till the centre of gravity, V, falls beyond the fore foot, B; and then being ready to fall, he presently prevents it, by taking up the hind foot, and by bending the joints of the hip, knee, and ancle, and suddenly translating it forward to T beyond the centre of gravity, and thus he gains a new station.

After the same manner, by extending the foot and leg H B, and thrusting forward the centre of gravity beyond the foot S, and then translating the foot B forward, he gains a third station: and thus walking is continued at pleasure.

Obs. 1. His two feet do not go in one right line, but in two lines parallel to one another; therefore a man walking has a libratory motion from one side to the other; and it is not possible to walk in a right line.

2. We walk on level ground easily and pleasantly; it is laborious to climb a hill, from the great flexure required of the joints to ascend, and from the stress they receive from the weight of the body in that position.

3. In *walking* we always set down one foot before the other be taken up; and therefore at every step we have both feet on the ground at once. But in *running* we never set one foot down till the other be up; so that at every step we have but one foot on the ground, and all the intermediate time none.

4. The walking of birds is not unlike that of man; only their weight is entirely supported by the strength of the muscles, since their joints are always bent. The feet of birds are also moved in two parallel lines.

5. When a *beast*, a horse for example, *stands*, the line of gravity must fall within the quadrilateral made by his four feet. When he *walks*, he has always three on the ground, and one up, as you see in the figure.

Illus. Thus, suppose he first lift the hind foot C. Before he does this, by extending his leg backwards, he thrusts forward his body and the centre of gravity; then taking up the foot C he moves it forward to F. Then he immediately takes up the fore-foot B on the same side, and carries it to H;—then he takes up the hind-foot D, and translates it forward; and then the fore-foot A; then F again, and so on.

Let any boy walk on all-fours, and one hand and one leg on one side, one hand and one leg on the other, is the natural action of the horse walking.

2. When the horse *trots*, he takes up two feet together and sets down two together, diagonally opposite.

3. When he *gallops*, he takes up his feet one by one, and sets them down one by one; though some animals strike with the two fore-feet nearly at once, and the two hind-feet nearly at once; and have not above two feet on the ground at once.

6. Animals of 6 or more feet, as the caterpillar, take up the hindmost first, then the next, and then the next in order to the foremost, *all on one side*; and after that, all the feet *on the other side*; in the same order, beginning at the *last*. If the caterpillar were to take up its foremost feet first, it would move backwards, as we see a crab do on the sea-shore.

Questions for Examination.

1. Illustrate upon what principles are the various motions of animals regulated.

2. Describe the action of a man in walking, and how he preserves his centre of gravity: the species of line he makes in walking; and how it is difficult to climb hills.

3. How does he move his feet in walking and running?

4. To what is the walking of birds likened?

5. Illustrate the motion of a horse to preserve his centre of gravity in walking, trotting, and galloping.

6. Describe now the motion of animals of more than six feet, as the caterpillar and the crab.

CHAPTER VII.

MECHANICAL POWERS.

Introduction.

SECTION I.

1. WITH MECHANICAL POWERS which are simple engines, we raise weights, move heavy bodies, and overcome resistances.

2. Every machine is composed of *one* or *more* of these powers; sometimes it is composed of several of them combined.

3. In considering this branch of science we take the following things for granted, though not strictly true:

1. That *a small portion of the earth's surface,* which is nearly spherical, *be considered as a plane.*

2. That all bodies be supposed to descend in lines parallel to each other; for though all bodies really tend to the centre of the earth, and would thence take the direction of so many radii to the centre of a sphere; yet the distance from which they fall is comparatively so small, and their inclination towards each other so inconsiderable, that it is thence entirely disregarded.

3. That all *planes* be considered perfectly *smooth,* that *levers* are *inflexible* and without *thickness,* or *weight,* that *cords* are perfectly *pliable:* and that *machines* are without *friction* and *inertia.*

4. Three things are also to be considered in treating of mechanical engines.

1. The *weight* which we are required to raise.
2. The *power* by which we are to raise that weight.
3. The *instrument* or engine by which this operation is to be effected.

5. The mechanical powers are generally reckoned six: viz.

1. THE LEVER,	4. THE INCLINED PLANE,
2. THE PULLEY,	5. THE WEDGE,
3. THE WHEEL & AXIS,	6. THE SCREW.

Obs. These six powers are however reducible to two; for the pully and wheel are only assemblages of levers, and the wedge and screw compose inclined planes.

6. To calculate the power of a machine, it is usually considered in a state of equilibrium; that is, in the state, when the power which is to overcome the resistance, just balances that resistance. Having discovered what quantity of power will be requisite for this purpose, it will then be necessary to add as much more as may overcome the friction and weight of the machine itself, and give it the necessary velocity.

Questions for Examination.

1. What are the *mechanical* powers? and their importance, what?
2. Of *what* is every machine composed?
3. What *three things* are taken for granted, in considering this branch of science?
4. What *three things* are also to be considered in the treating of the mechanical powers?

5. *What are* the mechanical powers? and to what *number* may they be reduced?
6. How do we proceed in *calculating* the power of a machine?

SECTION II.

Of the Lever.

1. The LEVER is the simplest of all machines, being only a straight bar of iron, of wood, or of some other material, supported on, and moveable round, a prop called the *fulcrum*.

Obs. In the lever, there are three circumstances to be attended to, in considering its use or application.
1. The *fulcrum*, or prop by which it is supported, or on which it turns as an axis, or centre of motion.
2. The *power* to raise and support the weight: and
3. The *resistance* or weight to be raised or sustained.

2. The *point of suspension* is that point where the weight really is, or from which it hangs freely.

3. The power and the weight are always supposed to act at right angles to the lever, except it be otherwise expressed.

4. There are three sorts of levers, which are distinguished according to the different situations of the fulcrum, or prop, and the power, with respect to each other.

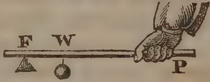
1. When the *prop* is placed between the *power* and the *weight*.
2. When the *prop* is at *one end* of the lever, the *power* at the *other*, and the *weight* between them.

3. When the *prop* is at *one end*, the *weight* at the *other*, and the *power* applied between them.

5. A lever of the first kind is principally used for loosening rocks and large stones; (or raising weights to small heights, in order to get ropes under them, or other means of raising them to still greater heights: and it is the most common species of lever.

Example. If a stone (W), weighing 500 pounds, is to be raised *one foot* by a man acting at (P), who can only lift 100 pounds, he cannot raise it, unless he contrive to make his arm move five feet, while the stone moves only one foot, because $100 \times 5 = 500 \times 1$; therefore to effect this, the arm of the lever (P F) must be five times as long as the arm between (F) and the weight, in order that the power and weight may balance each other.

This increase of motion in the arm is effected by the lever; because the motion of one end is in the same proportion to the motion of the other, as the distance of the two ends are from the fulcrum.



6. The annexed diagram exhibits a lever of the 2nd class, in which the advantage gained, is as great as the distance of the power (P) from the prop (F) exceeds the distance of the weight (W) from it.

Illus. This lever shews the reason why two men carrying a cask upon a pole, may bear unequal shares of the weight, each according to his strength; for it is well

known, that the nearer either of the men is to the burthen, the greater share of it he will bear; their shares of its weight are to either of them, in the inverse proportion of his distance from it.

Example. If the pole be eight feet long, and a cask be slung directly at its half length, at the end of the pole, each of the men will bear 56*lbs.* weight, supposing the cask to weigh 112*lbs.*; but if it be placed (as W) four times nearer the one man (F) than to the other, (P) the former (F) will bear four times as much weight as the latter (P), or 84*lbs.*

2. To this kind of lever may be reduced *oars, rudders of ships, cutting knives, &c.* which are fixed at one end.

7. The annexed diagram exhibits a lever of the third kind, in which the power (P) is between the weight (W) and prop (F). Thus, if the power and weight have changed places, from the former that there may be a balance between the power and the weight, in this third kind of lever, the *intensity* of the power must exceed the intensity of the weight just as much as the *distance* of the weight from the prop exceeds the distance of the power.

Illus. 1. A ladder, which is to be raised by the strength of a man's arm, represents a lever of this kind, where the fulcrum is that end of the ladder fixed against the wall, or upon which another man stands; the upper part of the ladder may be considered the weight, and the power the strength of the man applied to the raising of it.

2. The bones of a man's arm are generally referred to this sort of lever; for, when he lifts a weight by the hand, the muscle that exerts its force to raise that weight, is

fixed to the bone about one-tenth part as far below the elbow as the hand is. And the elbow being the centre round which the lower part of the arm turns, the muscle must, therefore, exert a force ten times as great as the weight that is raised.

3. The wheels in a clock, and in watch-work, may be reckoned levers of this kind; because the power that moves hem, acts near the centre of motion, by a pinion, and the resistance it has to overcome, acts against the teeth at the circumference.

Obs. 1. In *natural* levers the power is disadvantageously situated, owing to its being so near the centre of motion, but the loss of power is compensated by the beauty and compactness of the limb, and in the *artificial* lever last mentioned, the uniformity of the action occasioned by the force of the spring, can only be kept up by renewing the power of the first mover or spring, after a certain period.

2. The *balance* and the *statera* or *Roman steel yard*, are levers of the first kind; as are also *scissors, snuffers*, &c. which are made of two levers acting contrary to each other.

8. The HAMMER LEVER differs in nothing but its form, from a lever of the first kind. The name is derived from its use; that of drawing a nail out of wood by a hammer.

Illus. Suppose the shaft of a hammer to be *five* times as long as the iron part which draws the nail, the lower part resting on the board as a fulcrum; then, by pulling backwards the end of the shaft, a man will draw a nail with one *fifth* part of the power that he must use to pull it out with a pair of pincers; in which case, the nail would move as fast as the hand; but, with the hammer, the hand moves *five* times as much as the nail, by the time that the nail is drawn out.

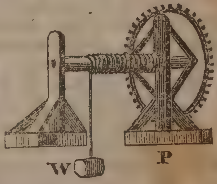
Questions for Examination.

1. What is the lever, and what three circumstances are to be attended to in considering its application?

2. What is the point of suspension?
3. How do the power and weight always act?
4. How many sorts of levers do we distinguish?
5. For what is a lever of the first kind generally used? How do you illustrate its application by an example and a diagram, which you are required to draw.
6. What is the advantage gained by the second kind of lever? How do you illustrate this from two men carrying a cask on a pole? What machines and instruments may be reduced to this kind of lever.
7. Describe the third kind of lever. Illustrate it from a ladder raised by a man. From the bones of a man's arm. How is the power situated in the natural and artificial levers respectively? And what machines and instruments belong to this kind of lever?
8. Describe the hammer lever: and illustrate your description from a man drawing a nail with a hammer

SECTION III.

Of the Wheel and Axle.



1. The annexed diagram exhibits one of the simplest construction, of the WHEEL and AXLE, a machine much used, but made in a variety of forms. You see from the figure, that this machine consists of a wheel fixed to an axle, or cylinder, so that both turn round together; sometimes it is merely a cylinder with projecting spokes, in which case the power is applied at the circumference of the

wheel, and the weight to be raised is fastened to a rope which coils round the axle or cylinder.

Illus. 1. The circumferences of different circles, bear the same proportion to each other as their respective diameters do; consequently, the advantage gained by this mechanical power is in proportion as the circumference of the wheel is greater than that of the axis, or as the diameter of the wheel is greater than the diameter of the axis. Hence, the velocity of the power will be to that of the weight, as the circumference of the wheel is to that of the axis, and that the power and the weight be in equilibrio, the power must, therefore, be to the weight in the inverse ratio of the circumferina of the wheel to that of the axis.

Example. Suppose a water-wheel to be 12 feet diameter, and the axle 1 foot, the power acting at the circumference of the large wheel moves over 12 times the space which the circumference of the axle moves: hence, 12 *cwt.* may be raised with the power of 1 *cwt.*

2. The wheel and axis may be considered as a *perpetual lever*, the centre of the axis being the fulcrum, and the long and the short arms, the diameter of the wheel, and the diameter of the axis. Now, from this it is evident, that the longer the wheel, and the smaller the axis, the stronger is the power of this machine; but then the weight must rise slower in proportion.

Example. A *capstan* is a cylinder of wood, with holes in it, into which are put bars or levers, to turn it round: these are like the spokes of a wheel without a rim.

Obs. In short, all *windlasses, cranes, mills, wind-mills,* and *water-mills,* are framed on the principle of the wheel and axle. The power, whatever it be, is applied to the *circumference* of a supposed large wheel, the circumference of which moves, in consequence, perhaps 10 miles an hour, while its axle, one-tenth of the diameter, moves but one mile an hour, consequently the strength of *one man,* at the *circumference* will be equal to that of *ten men* at the *axle.*

3. When the axle is turned by a winch fastened to it, which, in this respect, serves for a wheel, it will be more powerful in proportion to the largeness of the circle it describes, compared with the diameter of the axle.

Questions for Examination.

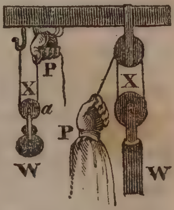
1. Describe to me the wheel and axle. What is the consequence of the circumferences of different circles, bearing the same proportion to each other, as their different diameters do? And what then is the ratio of the velocity of the power to that of the weight. Give me an example of a water-wheel 12 feet diameter.

2. Shew now what a perpetual lever is, what also is a capstan? What are windlasses, cranes, mills, &c.?

3. How is the axle turned?

SECTION IV.

Of the Pulley.



1. This mechanical power is exhibited in the annexed figure. The PULLEY as you see, is a small wheel (*a*) turning on an axis, with a drawing rope passing over it: the small wheel (*a*) is usually called a *sheeve*, and is so fixed in a *box* or *block*, as to be moveable round a pin passing thro' its centre.

2. Pulleys are two kinds; 1. *Fixed* as the pulley

of the left hand figure; and secondly, *moveable*, as the lower ones of the same figure, which rise and fall with the weight.

Obs. The *fixed pulley* gives no mechanical advantage, but is used only to change the direction of a power. By it a man may raise a weight to any height, without moving from the place in which he is.

2. The *moveable pulley*, on the contrary, doubles the power. A man may therefore raise twice as much by it, as by his strength alone: and by increasing the number of such pulleys, the force may be increased in any ratio whatever. The advantage gained by it in mechanics, is as two to one; consequently, a power of 10lbs. exerted by the hand (P) will balance a weight of 20lbs. (W)

3. The reason of this is evident. In raising the weight one inch, one foot, or one yard, both sides of the rope must be shortened as much; that is to say, the hand must move through two inches, feet, or yards, which shews as before, that the space through which the power moves, must always be in proportion to the advantage gained. In general, the advantage gained by pulleys, is found by multiplying the number of pulleys in the lower block by 2.

Obs. A pair of blocks with a rope, is called a *tackle*, as the right hand figure of the above diagram.

Questions for Examination.

1. Describe the pulley.
2. How many kinds of pulleys are there? and what is the advantage gained by each? as for example, 1st, by the fixed pulley; and 2dly, by the moveable pulley.
3. How do you prove that in the moveable pulley, the advantage is as two to one. Now what is a *tackle?*

Section V.

Of the Inclined Plane.

1. The annexed diagram shews you an IN-

CLINED PLANE, which you will perceive is merely a plain surface D A, inclined to the horizon B A; but as a mechanical power, it is of very great use, in moving weights from one level to another; as for example, for rolling up heavy bodies, such as casks, wheelbarrows, &c. We may form an inclined plane, by placing boards, earth, or other materials in a sloping direction.

Illus. The force wherewith a body (C) descends upon an inclined plane, is to the force of the absolute weight by which it would descend perpendicularly in free space, as the height (B D) of the plane is to its length (D A).

2. When a plane is inclined to the horizon one third of its whole length, any body (C) will be kept from rolling down that plane, by a power equal to the third part of the weight of the body: if the height of the plane be equal to half its length, a power equal to half the weight of its body will support it.

3. The less the angle of elevation, or the gentler the ascent is, the greater will be the weight which a given power can draw up, for the steeper the inclined plane is, the less does it support of the weight, and the greater is the tendency which the weight has to roll, consequently the more difficult for the weight to support it; hence the advantage gained by this mechanical power, is as

great as its length (A D) exceeds its perpendicular height (B D.)

Note. To the inclined plane may be reduced all *hatchets, chissels,* and other *edged-tools,* which are sloped on one side only.

Questions for Examination.

1. Define the *inclined plane,* and describe its use as a mechanical power. Now illustrate the force with which a body descends on an inclined plane.

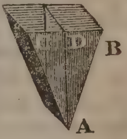
2. What is the consequence when a plane is inclined to the horizon one-third of its whole length? And what is said of a plane perpendicular to the horizon.

3. What is the nature of an inclined plane, when the weight will be greater, which a given power can draw up? and when does a body roll down the fastest?

SECTION VI.

Of the Wedge.

1. The WEDGE is shewn in this diagram. We consider the wedge as two equally *inclined planes* united at their bases, as may be seen from the figure.



Illus. The advantage gained by this mechanical power is in proportion as the length of the two sides A B, A C of the wedge is greater than the breadth of the back, B C, or as the length on one side, A B, is greater than B D, half the breadth of the back.

2. The wedge is a very great mechanical power, since not only wood, but even rocks can be split by it, which it would be impossible to effect by the lever, the wheel and axle, or the pulley. The force of the blow or stroke upon the wedge shakes the cohering parts of the

most compact body of stone, and thereby makes them separate more easily. This you may soon be convinced of if you have ever seen stone masons or quarriers at work; and when you split a piece of stick with a common table knife.

Note. Most of the instruments used in the common purposes of life are to be referred to the principle of the wedge.

Questions for Examination.

1. Describe the wedge and illustrate its advantage.
2. Now how does the wedge in some cases surpass the inclined plane, the lever, and the wheel and axle?

Section VII.

Of the Screw.

1. The SCREW, as you see by the annexed figure, is an inclined plane, used with a lever or winch to assist in turning it. It is therefore a compound engine, of great force, either in pressing bodies together, or in raising great weights.

Obs. The screw may be conceived to be made by cutting a piece of paper in the form of an inclined plane, and then wrapping it round a cylinder, when the edge of the paper will form a spiral line round the cylinder, which will answer to the thread of the screw.

2. The advantage gained by this mechanical power is in proportion as the circumference of the circle made by the lever, or winch, is

greater than the interval, or distance between the spirals or threads of the screw.

Example. Thus, supposing the distance of the spirals to be half an inch, and the length of the winch 12 inches, the circle described by the handle of the winch, when the power acts, will be 76 inches nearly, or about 152 half-inches; and consequently, 152 times as great as the distance between the spirals; and, therefore, a power at the handle, whose intensity is equal to no more than a single pound, will balance 152lbs. acting against the screw, and as much additional force as is equal to overcome the friction, will raise 152lbs.; and the velocity of the power will be to the velocity of the weight as 152 to 1.

3. Hence it appears, that the longer the winch is, and the nearer the spirals are to each other, so much the greater is the force of the screw.

Note. Almost all kinds of presses, common cork-screws, &c. act upon the principle of this mechanical power. When the screw acts in a wheel, it is called a *perpetual screw.* We have frequently seen several screws, properly applied, supporting a large building, while the foundation was mending or renewing.

Questions for Examination.

1. Describe the screw, and show me how it is made.

2. How is the advantage of this mechanical power estimated? Now give me an example to prove when the velocity of the power will be to the velocity of the weight as 152 to 1.

3. When is the force of the screw greatest? What are presses? The perpetual screw? And to what use are screws sometimes applied in repairing buildings?

SECTION VIII.

Of Compound Machines, &c.

1. Any one of the mechanical powers is capable of overcoming the greatest possible resistance in theory; yet, in practice, if used singly for producing very great effects, they would frequently be so very unwieldy and unmanageable, as to render it impossible to apply them. It is thence found more advantageous to combine them; so that the power may be more easily applied, and such other advantages obtained as are serviceable to man.

2. In contriving machines, simplicity ought particularly to be attended to; for a complicated machine is not only more expensive and more apt to be out of order, but there is also a greater degree of friction in proportion to the rubbing parts.

Obs. Whatever be the construction of a machine, the advantage gained by it will always be in proportion as the velocity of the power is to that of the weight, and so that this is obtained in the greatest degree that circumstances will admit, or that are necessary, then the fewer parts the better.

3. The velocity of a wheel is to that of a pinion or smaller wheel, which is driven by it in proportion to the diameter, circumference, or number of teeth in the pinion to that of the wheel.

Illus. If the number of teeth in a wheel be 60, and those of the pinion 5, then the pinion will go 12 times round while he wheel goes once round, because 60÷5 gives 12 for quotient.

4. Hence, if there are any number of wheels acting on so many pinions, we must divide the product of the teeth in the wheels by the product of those in the pinions, and the quotient will give the number of turns of the last pinion in one turn of the first wheel.

Example. Thus, if a wheel of 48 teeth acts on a pinion of 8, on whose axis there is a wheel of 40 driving a pinion of 6, carrying a wheel of 36, which moves a pinion of 6, carrying an index, then the number of turns made by the index will be found in this manner $\frac{48}{8} \times \frac{40}{6} \times \frac{36}{6} = \frac{69120}{288} = 240$, the number of turns which the index will make while the wheel goes once round.

5. Any number of teeth on the wheels and pinions having the same ratio, will give the same number of revolutions to an axis.

Example. Thus, $\frac{64}{10} \times \frac{50}{8} \times \frac{36}{6} = \frac{115200}{480} = 240$, as before. It therefore depends upon the skill of the engineer or mechanic to determine what numbers will best suit his design.

Obs. It is evident that the same motion may be performed either by one wheel and pinion, or by many wheels and pinions, provided the number of turns of all the wheels bear the same proportion to all the pinions which that one wheel bears to its pinion.

6. When a wheel is moved immediately by the power, it is called a *leader ;* if there is another wheel on the same axis it is called the *follower*.

Obs. Sometimes the same wheel acts both as a leader

and a follower. Therefore, as to multiply both the divisors and dividends by the same number, does not alter the quotient; in mechanical calculations, every wheel that is both a leader and a follower, may be entirely omitted.

2. The power of a machine is not at all altered by the size of the wheels, provided the proportions to each other are the same. Formerly the wheels of engines being mostly of wood, were made of a large size on account of strength, but now that cast iron wheels are mostly used, the smallness of their size gives them the advantage of occupying much less room.

7. *Fly-wheels.* In all machines the moving power is sometimes stronger and at other times weaker. To correct this, and render the motion uniform, an additional part, called a *fly*, is applied, which is generally either a heavy wheel or a cross bar loaded with equal weights. In general fly-wheels are employed to *equalize* the motion of a machine; they cannot in any other way *add* to its power.

8. *Friction.* In the application of all the mechanical powers, one-third is allowed to overcome the FRICTION of the surface, and the various other obstacles to which all machines are liable.

If a horizontal plane were perfectly smooth, a body would be free to move upon it in any direction, by the least force applied to it. But however smooth bodies may appear to the eye, yet if their surfaces be examined with a microscope we discover numberless inequalities; hence the prominent parts of one body fall into the hollows of another, and they become as it were locked together; and therefore in moving them over each, one of the bodies must be raised up, or its prominences broken off: this is what is called *friction*.

9. *Friction* is greater in bodies in proportion to their weight or pressure against each other. It does not increase much in proportion to the surface, although it does in some degree. It also increases in proportion to the velocity of the moving bodies.

Obs. 1. Wood slides more easily upon the ground or earth in wet weather than in dry, and more easily than iron in dry weather, but iron slides more easily than wood in wet weather.

Example. A cubic piece of smooth soft wood, eight pounds in weight, moving upon a smooth plane of soft wood at the rate of three feet every second, has a friction equal to above two-thirds of its weight. Soft wood upon hard wood has a friction equal to one-sixth part of its weight, and hard wood upon hard wood has a friction equal to about one-eighth part of its weight.

Obs. 2. In wood rubbing upon wood, oil, grease, or blacklead, properly applied, makes the friction two-thirds less. Wheel-naves, when greased, have only one-fourth of the friction they would have if wet.

Examples of Metals. When polished steel moves on steel or pewter, properly oiled, the friction is about one-fourth of the weight; on copper or lead, one-fifth of the weight; on brass, one-sixth; and metals have more friction when they move upon metals of the same kind than when they move on metals of different kinds.

Obs. 3. The friction of a single lever is very little. The friction of the wheel and axle is in proportion to the weight, velocity, and the diameter of the axle; the smaller the diameter of the axle, then the less will be the friction.

4. The friction of pulleys is very great, on account of the smallness of their diameters in proportion to that of their axes, as well from their bearing against the blocks as from the wearing of their holes and axles.

5. In the wedge and screw there is a great deal of friction. Screws with sharp threads have more friction than

those with square threads, and endless screws have more than either.

Questions for Examination.

1. What are compound machines? What their advantages? How are their power and weight estimated? Illustrate this from a combination of the wheel and axle with pulleys.

2. Why ought simplicity to be particularly attended to in compound machines?

3. What is the ratio of the velocity of a wheel to that of a pinion? Illustrate this from a wheel of 60 and a pinion of five teeth.

4. How do we ascertain the number of turns of the last pinion in one turn of the first wheel? Prove your rule by an example.

5. How do we obtain the same number of revolutions to an axis? An example is required.

6. Define what leaders and followers are. How they are considered in mechanical calculations. And how the power of a machine is not altered by the size of its wheels.

7. What are fly wheels? What is their use?

8. What is friction? Describe it fully.

9. What increases friction? When do wood and iron respectively slide the more easy on the ground?

When has a piece of wood 8lbs. weight a friction equal to two-thirds of its weight? When one-eighth part?

When has polished steel a friction of one-fourth, one-fifth, and one-sixth of its weight?

What of the friction of a single lever, and of the wheel and axle?

Why have pulleys much friction; and also the wedge and screw?

CHAPTER VIII.

OPTICS.

Section I.

Terms defined and explained.

1. The science of vision is termed optics, and it depends on the properties of light. Light consists of inconceivably small particles, which are projected in all directions, with amazing velocity, from the luminous body.

2. Light travels at the rate of 150,000 miles in a second of time. The rays of light move in straight lines, as may be proved by the impossibility of seeing through a crooked tube.

Corol. Hence it follows that the intensity of light decreases, as the square of the distance from the luminous body increases; that is to say, if you remove an object to twice the distance from the luminous body, it will be enlightened only one-fourth part as much as before; if to three times the distance, it will be illuminated only one-nth as much, and so on in geometric progression.

3. By a ray of light, we mean the motion of a single particle, represented by a straight line.

4. Any number of rays issuing from a point is called a pencil of rays.

5. A medium is any pellucid or transparent body which suffers light to pass through it, as water, air, and glass.

6. Parallel rays are such as move always at the same distance from each other.

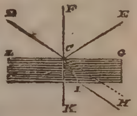
7. When rays continually recede from each other, they are said to diverge.

8. When they continually approach towards each other, they are said to converge.

9. The point at which converging rays meet, is called the focus.

10. The point towards which they tend, but at which, by some obstacle, they are prevented from arriving, is called the imaginary focus.

11. When rays, after passing through one medium, on entering another medium of a different density, are bent out of their former course and made to change their direction, they are said to be refracted; as the ray B C, which, when it enters the medium C G, instead of proceeding in the same direction C H, is made to move in the direction C I.



12. When the rays strike against a surface and are sent back again from that surface, they are said to be reflected, as C E.

13. The incident ray is that which comes from a luminous body, and falls upon the reflecting surface, as B C.

14. The angle of incidence is contained between the incident ray B C and a perpendicular

to the reflecting surface in the point of reflection, as the angle B C F.

15. The angle of reflection is contained between the perpendicular F C and the reflected ray C E, as the angle F C E.

16. The angle of refraction is contained between the refracted ray C I and the perpendicular C K, as the angle I C K.

If rays of light, after passing through one medium, enter, perpendicular to its surface, another medium of a different density, they proceed through this medium in the same direction as before. Thus the ray F C proceeds to K, in the direction of a straight line.

But if they enter obliquely to the surface of a medium, either denser or rarer than that in which they moved before, they are made to change their direction in passing through that medium.

If the medium which they enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface.

Thus, B C, upon entering the denser medium L G, instead of proceeding in the same direction C H, is bent into the direction C I, which makes a less angle with the perpendicular C K.

On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. Thus, if I C were a ray of light which had passed through the denser medium L G, on arriving at the rarer medium, it would move in the direction B C, which makes a greater angle with the perpendicular.

This refraction is greater or less (that is to say, the rays are more or less bent or turned aside from their course), as the second medium through which they pass is more or less dense than the first.

Thus, light is more refracted in passing from air into glass, than from air into water, glass being denser than water.

17. A mirror or speculum is an opaque body, the surface of which is very smooth and finely polished, so that it may reflect the rays of light which fall upon it, and by this means represent the images of objects presented to it.

Mirrors are generally made of metal or of glass, polished on one side and silvered on the other, and are either plain, convex, or concave.

18. In plane mirrors, the surfaces are perfect planes, and their section is a straight line: such are called looking-glasses,

19. In convex mirrors, the middle parts are more prominent than their extremities or edges; their sections are curves, either circular, elliptic, parabolic, or hyperbolic. Thus C D is the section of a mirror, whose surface is part of a globe: this sort is mostly in use.

20. In concave mirrors, the surfaces sink in with a hollowness, like a saucer. The sections of these may be curves, as various as the last. E F is a concave mirror, whose surface is part of the internal surface of a hollow sphere, and this is the most common kind.

21. A lens is a piece of glass ground so as to collect or disperse the rays of light which pass through it. Lenses are of different shapes, and from thence receive different names.

22. Thus a plano-convex, has one side flat, and the other convex, as A. (See the figure in the next page.)

23. A plano-concave, is flat on one side, and concave on the other, as B.

24. A double convex, is convex on both sides, as C.

25. A double concave, is concave on both sides, as D.

26. A meniscus, is convex on one side, and concave on the other, as E.

27. A line passing through the centre of a lens, as F G, is called its axis.

Questions for Examination.

1. Define the science of optics.
2. At what rate does light travel, and in what direction do its rays flow?
3. 4. Define a ray of light, and also a pencil of rays.

Note. On the remaining definitions we leave the tutor to question the pupil, without framing the series, which would be but a repetition of the definitions.

Section II.

Refraction.

1. To prove the refraction of light, place an empty basin into a dark room, make a small hole in the window-shutter, so that a beam of light may fall upon the bottom of the basin, where

you may make a mark. Fill the basin with water, without moving it out of its place, and you will see that the ray, instead of falling upon the mark you first made, will fall on another part of the basin.

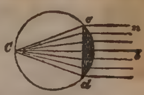
If a piece of looking glass be laid on the bottom of the basin, the light will be reflected from it, and will be observed to suffer the same refraction as in coming upon it, only in a contrary direction. If the water be a little muddy, by putting a few drops of milk into it, and if the room be filled with dust, the rays will be rendered more visible.

Put a piece of money into a basin when empty, and walk back till you have just lost sight of the money, which will be hid by the edge of the basin. Then pour water into the basin, and you will see the money distinctly, though you look at it exactly from the same spot as before.

If the rays of light falling upon a piece of flat glass, are refracted into a direction nearer to the perpendicular, while they pass through the glass; but after coming again into air, they are refracted as much in the contrary direction; so that they move exactly parallel to what they did before entering the glass. But on account of the thinness of the glass, this deviation is generally overlooked, and a ray of sight is considered as passing directly through the glass.

Proposition I.

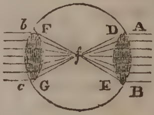
2. When parallel rays, as *n b*, fall on a plano-convex lens, *c d*, they will be so refracted, as to unite in a point, *c*, behind it; this point is called the principal focus, or the focus of parallel rays; the distance of this point from the middle of the glass, is called the focal distance,



and it is equal to twice the radius of the sphere, of which the lens is a portion.

Proposition II.

3. If parallel rays, as A B fall upon a double convex lens, D E, they will be refracted, so as to meet in a focus *f*, which is the centre of the sphere or lens, for *f* E is its semi-diameter.



Since all the rays of the sun which pass through a convex glass, are collected in its focus, the continued force of their heat is collected in that part. Hence we see the reason why a convex glass causes the sun's rays to burn after passing through it.

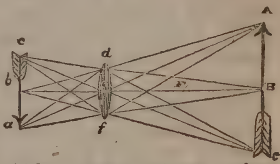
All those rays cross the middle ray in the focus *f*, and then diverge from it, to the contrary sides, in the same manner as they converged in coming to it.

If another glass, F G, of the same convexity as D E, be placed in the rays at the same distance from the focus *f*, as D E is, it will refract them so, that, after going out of it, they will be all parallel, as *b*, *c*; and they will go on in the same manner as they came to the first glass D E, but on the contrary sides of the middle ray, passing through the focus *f*.

Proposition III.

4. If any object, A B C, be placed beyond the

the focus f of the convex glass $d\,e\,f$, some of the rays proceeding from every point of the object, on the side next the glass, will fall upon it, and after passing through it, they will be converged into as many points on the opposite side of the glass, where the image of every point will be formed, and consequently the image of the whole object, which will be inverted.



Illus. 1. Thus, the rays A d, A e, A f, flowing from the point A, will converge in the space $d\,a\,f$, and by meeting at a, there form the image of the point A. The rays B d, B e, B f, issuing from the point B, will be united at b by the refraction of the glass, and will there form the image of the point B. And the rays C d, C e, C f, proceeding from the point C, will concentrate at c, where they will form the image of the point C, and so of all the intermediate points between A and C.

If the object A B C be brought nearer to the glass, the picture $a\ b\ c$ will be removed to a greater distance, because a greater number of rays flowing from every single point, and falling more divergent upon the glass, cannot therefore be so soon collected into the corresponding points behind it. Consequently, if the distance of the object A B C be equal to the distance e F of the focus of the glass, the rays of each pencil will be so refracted by passing through the glass, that they will go out of it parallel to each other, and therefore there will be no picture formed behind the glass.

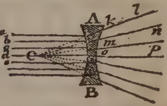
3. If the focal distance of the glass, and the distance of the object from the glass be known, the distance of the picture from the glass may be found by the following rule: Multiply the distance of the focus by the distance of the

object, and divide the product by their difference; the quotient will be the distance of the picture.

4. The picture will be as much bigger or as much less than the object, as its distance from the glass is greater or less than the distance of the object; for as B *e* : *e b* :: A C : *c a*; so that if A B C be the object, *c b d* will be the picture; or if *c b a* be the object, A B C will be the picture.

Proposition IV.

5. When the parallel rays, as *a*, *b*, *c*, *d*, *e*, pass through a concave lens, A B, they will diverge, after passing through the glass, as if they had come from a radiant point C, in the centre of the convexity of the glass. This point is called the virtual or imaginary focus.



Illus. Thus the ray *a*, after passing through the glass A B, will go on in the direction *k l*, as if it had proceeded from the point C, and no glass had been in the way. The ray *b* will go on in the direction *m n*, the ray *c* in the direction of *o p*, &c. The ray *d*, falling directly upon the middle of the glass, suffers no refraction in passing through it, but goes on in the same rectilinear direction as if no glass had been in the way.

Had the glass been concave on one side only, and were the other side quite flat, the rays would have diverged, after passing through it, as if they had come from a radiant point at double the distance of C from the glass, that is to say, as if the radiant point had been at the distance of a whole diameter of the convexity of the glass.

Questions for Examination.

1. How do you prove the refraction of light?

2. Define the focus of parallel rays, and explain what is meant by the focal distance?

3. How does a convex glass cause the sun's rays to burn after passing through it.

4. Illustrate how an object is inverted, when the rays of light pass through a convex glass.
5. Illustrate the imaginary focus.

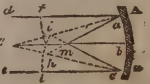
SECTION III.

Of Reflection; or, the Principle on which the properties of Mirrors depend.

1. When a ray of light falls upon any body, it is so reflected, that the angle of incidence is equal to the angle of reflection; and upon this principle the properties of mirrors depend.

Illus. Thus if parallel rays, as *d f a*, C *m b*, *e l c*, fall upon a concave mirror A B, (which is not transparent, but has only the surface *a b c* of a clear polish), they will be reflected back from that mirror, and meet in a point *m*, at half the distance of the surface of the mirror from C, the centre of its concavity; for they will be reflected at as great an angle from the perpendicular to the surface of the mirror as the angle at which they fell upon it with regard to that perpendicular; but on the opposite side thereof.

For let C be the centre of concavity of the mirror A *b* B, and let the parallel rays *d f a*, C *m b*, and *e l c*, fall upon it at the points *a*, *b* and *c*. Draw to these points the lines C *a*, C *b*, and C *c*, from the centre, and these lines will be perpendicular to the surface of the mirror, because they proceed to it like so many radii from its centre. Make the angle C A *h*, equal to the angle *d a* C, and the line *a h*, which will be the direction of the ray *d f a*, after it is reflected from the point of the mirror, so that the angle of incidence *d a* C, is equal to the angle of reflection C *a h*, the rays making equal angles with the perpendicular C *i a* on its opposite sides.



2. Draw also the perpendicular C *h c* to the point *c*, where the ray *e l c* touches the mirror; and the line *c* having made the angle C *c i*, equal to the angle C *c e*, will

be the course of the ray *e l c*, after it is reflected from the mirror.

3. The ray C *m b*, which ought to pass through the centre of concavity of the mirror, by falling upon it at *b*, perpendicularly to the surface, it is reflected back from it in the same line *b m* C, because the mirror is not transparent.

All these reflected rays meet in the point *m*; and in that point the image of the body which emits the parallel rays *d a*, C *b*, and *e c*, will be formed; which point is distant from the mirror equal to half the radius *b* C, of its concavity.

2. The rays which proceed from any celestial object may be esteemed parallel at the earth; and therefore the images of that object will be formed at *m*, when the reflecting surface of the concave mirror is turned directly towards the object. Hence the focus of the parallel rays is not in the centre of the mirror's concavity, but half way between the mirror and that centre.

3. The rays which proceed from any remote terrestrial object are nearly parallel at the mirror; not strictly so, but come diverging to it in separate pencils, or, as it were, clusters of rays, from each point of the side of the object next the mirror; therefore, they will not be converged to a point at the distance of half the radius of the mirror's concavity from its reflecting surface, but in separate points at a distance a little greater from the mirror. And the nearer the object is to the mirror, the farther these points will be from it; and an inverted image of the object will be formed in them, which will seem to hang pendant in the air, and will be seen by an eye placed beyond it (with regard to the mirror), in all re-

spects like the object, and as distinct as the object itself.

Questions for Examination.

1. How do you prove that the angle of incidence is equal to the angle of refraction?

2. Whence is it that the focus of parallel rays is not the mirror's concavity?

3. What direction do rays take when proceeding from any terrestrial object, as to the mirror?

SECTION IV.

The Refrangibility of Light or Colours.

1. LIGHT is composed of three primitive colours—*red, blue, and yellow*, but it has been considered as composed of seven; these, however, are not all primitive colours, but some of them are compounds.

In treating of refraction, we have hitherto supposed that all light, in passing out of one medium into another of a different density, is equally refracted in the same, or in like circumstances. Light, however, is not a simple homogeneous body, but is compounded of different species; and each species is disposed both to suffer a different degree of refrangibility, in passing out of one medium into another, and to excite in our mind the idea of a different colour from the rest; and bodies appear of that colour, which arises from the composition of the colours, which the several species they reflect are disposed to excite.

2. The colours of objects are essentially altered by the light in which they are seen: thus, the colours of various pieces of silk or woollen stuff are not the same by day as by candle light;

but there is a common experiment which will prove that *colour is not in the objects*, but in the light by which they are seen.

Let a pint of common spirit (the cheapest will answer as well as the best, British brandy for instance) be poured into a soup-dish, and then set on fire: as it begins to blaze, let the spectators stand round the table, and let one of them throw a handful of salt into the burning spirit, still keeping it stirred with a spoon. Let several handfuls of salt be thus successively thrown in; the spectators will see each other frightfully changed, their colours being altered into a ghastly blackness. It is plain, then, that the solar rays are composed of matter different from the light which is emitted from this flame; and the truth is, that the light of a candle is somewhat different from both.

3. But the genius of Newton has enabled us to go still farther in ascertaining the nature of light. He has untwisted its rays and analized it with as much expertness as a chemist analizes any physical substance, and has divided it into its component parts. To this noble discovery the great philosopher was led rather by accident than design; but a mind such as Newton's was able to improve whatever hints chance submitted to his view. It was in attempting to rectify the errors arising from the aberration of light in the glasses of the telescope that his attention was directed to the wonderful effect which is produced by a prism.

Illus. The prism of the opticians is a triangular piece of glass, *(as A B C, Fig. 2, Plate I.)* of the length of about three inches. If, then, a small hole, F, is made in the window shutter, E G, of a dark chamber, and a beam of light, S F, proceeding directly from the sun (for the experiment

will only succeed when the sun shines,) is made to pass through the prism, A B C, an image of the sun, P S, will be represented on the sheet of paper, M N, fixed to the opposite wall. But you will observe two very extraordinary circumstances attending this representation of the sun:

First, that the figure is not round but oblong, and, secondly, if you will observe the figure in the plate, you will see that it is intended to represent different colours, and in the real image, these colours will be found extremely vivid. On measuring the image, which philosophers have agreed to call a SPECTRUM, *Sir Isaac Newton* found that, at the distance of eighteen feet and a half from the prism, the breadth of the image was two inches and a half, and its length ten inches and one quarter, that is, nearly five times its breadth. The sides were right lines distinctly bounded, and the ends, P T, were semi-circular, as in the plate.

From this it was evident that it was still the image of the sun, but elongated by some refractive power in the glass. In the image P T, the colours succeeded in this order from the bottom at T, to the top at P, namely *red, orange, yellow, green, blue, indigo, violet.*

2dly. Unable as yet to account for the phenomenon, he was induced to try the effect of two prisms, and he found that the light which, by the first prism, was diffused into an oblong, was by the second reduced to a circular form, as regularly as if it had passed through neither of them.

After various conjectures and experiments he had recourse at length to what he calls the *experimentum crucis.* At the distance of about twelve feet from the prism, which was close to the aperture F, he placed a board which might receive the image in the same manner as the sheet of paper M N. In this board there was also a small hole, through which some of the light might pass; behind this hole, then, he placed a second prism, and by moving the first prism, he made the several parts of the image cast by it on the board, to pass successively through the hole, so as to be refracted again upon the wall by the second prism.

He found then, that the different colours of the spec-

trum, when permitted to pass through the hole in the board, were incapable of further decomposition; that the *red* rays continued red, the *orange*, orange, and so on of the others. The cause of the phenomenon, therefore, was no longer a secret. It was plain that every beam of light consisted of particles different in colour, or which rather have the effect of producing different colours, and that all of them blended together formed *white*.

It was further evident, that the particles of one colour were more refrangible than those of another; and therefore those that formed the upper part of the image or spectrum suffered a much greater refraction than those at the bottom: in other words, were more under the influence of the attractive powers of the glass.

Hence it was further evident, why the figure or spectrum was of an oblong form instead of being round; for the particles of light being differently refrangible, were spread out longitudinally by the action of the prism.

4. An experiment will convince you that white light is no more than a compound of these particoloured rays or particles.

For, if, instead of the sheet of paper M N, you substitute the large convex glass D. (see fig. 3rd) the scattered rays will be converged and united at W, where, if the paper is placed to receive them, you will see a circular spot of a lively white. At W also the rays will cross each other; and if the paper is removed a little further, you will see the prismatic colours again displayed as at R V, only in an inverted order, owing to the crossing of the rays.

5. Any of these colours, except *red* and *violet*, may be made by mixing together the two prismatic colours. Thus yellow is made by mixing together a due proportion of orange and

green; and green may be made by a mixture of yellow and blue.

6. The theory of colours is, therefore, now completely unfolded. Those bodies, or those parts of bodies, which have the property of reflecting only the red-making rays, will appear red; those which reflect the violet will be violet, &c.; and those which reflect some rays of one colour and some of another, will be the intermediate shade or colour between both; and as white is a compound of all the seven primary colours, so black is an entire deprivation of them all; and when an object appears black, the light is completely absorbed, or at least not reflected by it.

To prove, however, still more forcibly that colour is not in the objects, but in the light itself, no object whatever can reflect any other kind of light than that which is thrown upon it; and when any one of the primitive rays has been separated from the rest, nothing can change its colour. Send it through another prism, expose it in the focus of a burning glass, yet still its colour continues unaltered; the red ray will still preserve its crimson, and the violet its purple beauty; whatever object falls under any of them soon gives up its own colour, though ever so vivid, to assume that of the prismatic ray.

Experiments.

Place a thread of scarlet silk under the violet-making ray, the ray continues unaltered, and the silk instantly becomes purple. Place an object that is blue under a yellow ray, the object immediately assumes the radical colour.

In short, no art can alter the colour of a separated ray; it gives its tint to every object, but will assume none from

any; neither reflection, refraction, nor any other means can make it forego its natural hue; like gold it may be tried by every experiment, but it will still come forth the same. In whatever manner we consider the colour of a single prismatic ray, we shall have new cause to admire the beauties of nature. Whatever compositions of colouring we form, if examined with a microscope, they will appear a rude heap of different colours unequally mixed.

If by joining, for instance, a blue with a yellow, we make the common *green*, it will appear to the naked eye moderately beautiful; but, when we regard it with microscopic attention, it seems a confused mass of yellow and blue parts, each particle reflecting but one separate colour; but very different is the colour of a prismatic ray; no art can make one of equal brightness, and the more closely we examine it, the more simple it appears. To magnify the parts of this colour could be but to increase its beauty.

7. The red and orange rays, we have seen, are least subject to refraction, or are least turned out of their way by the interposition of glass; they are therefore, we may conclude, either larger than the rest, or propelled with greater force; in technical language, they have the greatest momentum.

Agreeably to this we find that when the eyes are very weak, they can scarcely support a scarlet colour; its impressions are too powerful, and next to the solar beam itself, dazzle and disturb the organ. On the contrary, the more refrangible the rays (the violet for instance) the less forcibly they strike the eye; and green, the intermediate colour, is the most agreeable, and is that in which Providence has chosen to array the meadows and the woods.

Questions for Examination.

1. Of what colours is light composed?

2. How do you prove that the colour of objects is in the light alone?

3. Describe the prism, and show how it separates the different species of light.

4. How do you prove that white light is no more than a compound of parti-coloured rays?

5. How may any of these colours be made?

6. How do you prove that different bodies have different powers of reflecting different sorts of rays; as red, red?

7. What colours are most agreeable to the eye?

Section V.

Of the Rainbow.

1. Of all the objects of nature the rainbow exhibits the prismatic colours in the greatest perfection. It is indeed a natural prism and separates the component particles of light with the same accuracy and precision.

The rainbow was one of those phenomena which astonished and perplexed the ancients; and, after many absurd and unsuccessful conjectures, their best philosophers, Pliny and Plutarch, relinquished the enquiry, as one which was above the reach of human investigation. In the year 1611, Antonio de Dommis, made a considerable advance, however, to the true theory, by suspending a glass globe in the sun's light, when he found, that, while he stood with his back to the sun, the colours of the rainbow were reflected to his eye in succession by the globe as it was moved higher or lower.

2. He was, however, unable to account for the production of the different colours, as the experiments with the prism had not yet been made; it was reserved for Newton to perfect the discovery.

To begin, however, with the experiment of the former philosopher, let us suppose ourselves in his place.

Each drop of rain may be considered as a small globe, which within a certain range will refract and reflect a ray of light. But to make this matter still plainer, let us for the present imagine three drops of rain, and three degrees of colours in the section of a bow (fig. 4). It is evident that the angle C E F is less than the angle B E F, and that the angle A E F is the greatest of the three. The largest angle then is formed by the *red* rays, the middle one consists of the *green*, and the smallest is the *purple*. All the drops of rain, therefore, that happen to be in a certain position to the eye of the spectator, will reflect the *red* rays, and form a band or semicircle of *red*; to those again in a certain position will present a band of *green*, &c. If he alters his station, the spectator will see a bow, though not the same bow as before; and if there are many spectators, they will each see a different bow, though it appears to be the same.

The phenomenon assumes a semicircular appearance, because it is only at certain angles that the coloured or refracted rays are visible to our eyes, as is evident from the experiment with the glass globe, which will only refract the rays in a certain position. The least refrangible or red make an angle of forty-two degrees two minutes, and the most refrangible or violet, an angle of forty degrees seventeen minutes. Now if a line is drawn horizontally from the spectator's eye, it is evident that angles formed with this line, of a certain dimension in every direction, will produce a circle, as will be evident by only attaching a cord of a given length to a certain point, round which it may turn as round its axis, and in every point it will describe an angle with the horizontal line, of a certain and determinate extent.

3. As the cause of colours must be now apparent to you, and as it is evident that they must proceed from some quality in bodies or their surfaces, which causes them to reflect rays of a particular hue, you will easily understand why some

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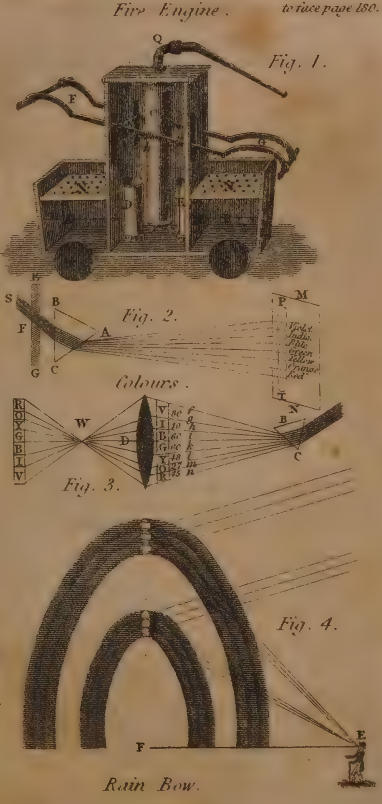


Engraved for Pinnock & Maunders Elements of Nat. & Ex. Phil. by Sid. Hall.

bodies, which are called semi-pellucid, afford one colour by reflected, and another by transmitted light.

The truth is, the beam of light passing through them is dissected and separated, and part of one colour is permitted to pass through, and part is sent back. If a solution of a wood called lignum-nephreticum is put into a clean phial, when viewed only by the reflected light which falls upon it, the solution will appear blue; but if held up against the light, and seen through, the colour will be a fine yellow. The same is found to be the case with some precious and some glass compositions. Thus, if a small quantity of arsenic is mixed in the composition of glass, the mass will appear blueish white by the reflected light, but orange by that which is transmitted through it. The blue colour of the sky may be accounted for upon this principle. The atmosphere may be considered as a semi-pellicid medium, which is loaded with small and light particles of vapour, and these particles may be compared with the particles of arsenic, which are mingled in the glass above mentioned. If the air is very heavily charged with these vapours, therefore, a large proportion of the light will be reflected, and that dusky whiteness appears which distinguishes mists and fogs; but in a clear state of the atmosphere, only the weaker and more refrangible rays, such as the blue, violet, &c. are reflected, and hence proceeds the blue colour of the sky.

On the same principles depends the green colour of the sea. It is a muddy mass, charged with heterogeneous particles. All the more refrangible rays, therefore, are reflected; while the stronger rays, the red, orange, &c. are transmitted. Thus, Dr. Halley, in a diving bell sunk many fathoms deep in the sea, observed, that when he extended his hand out of the bell into the water, the upper part of it was red, and the lower part a blueish green. The redness was occasioned by the strong red rays, which in their progress through the mass of water were intercepted and

reflected by his hand; while on the contrary, the heterogeneous particles dispersed through the water reflected only the refrangible rays, so as to afford the appearance of green. These principles, applied to many others of the phenomena of nature, will serve to explain their causes; and if they excite you but to use your own understandings, and to think for yourselves, this sketch of the phenomena of light and colours will be of more essential service to you than the most laboured detail.

Questions for Examination.

1. Whence is the rainbow one of the most splendid phenomena of nature, and what ideas had the ancients of it?
2. How do you illustrate the principle of the phenomenon?
3. How do some bodies afford one colour by reflected and another by the transmitted light.

Section V.

Description of the Eye.

1. To understand the science of vision thoroughly, we must describe the organ of sight, the eye, which every one knows is situated below the forehead. The eye is placed in a bony cavity, called the orbit, which is lined with fat, thus forming a soft bed for it to rest upon, and to facilitate its various movements.

Those prominent arches of hair which are called the eyebrows, defend the eyes from the light, when it is too strong, and prevent their being incommoded by any substances that might slide down the forehead, and thence fall into the eyes.

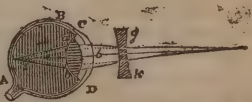
The eyelids, like too substantial veils, protect and

cover the eyes when we are asleep; when we are awake, they diffuse, by their motion, and by peculiar secreting organs, a fluid over the eye, which cleans and polishes it, and thus renders it fitter for transmitting the rays of light.

That the eyelids may shut with greater exactness, and not fall into wrinkles when they are elevated or depressed, each edge is stiffened by a cartilaginous arch. The eye-lashes, like two palisadoes of short hair, proceed from these cartilaginous edges, warning the eye of danger, protecting it from straggling motes, and warding off the wandering fly. The eye itself is of a globular form, but more protuberant on the fore-part than behind.

It is composed of three coats, or leguments, one covering the other, and inclosing three different substances, called humours.

The Coats of the Eye.



2. A B C D is a section of the globe of the eye, the three concentric circles representing the three coats, the sclerotica, the choroides, and the retina.

The external coat, or membrane, is called the sclerotica: it is strong, elastic, and of a white colour, resembling parchment; the hinder part is very thick and opaque, but it grows gradually thinner, as it approaches the part where the white of the eye terminates. A circular portion of it in front is perfectly transparent, and more convex than the rest: this is called the cornea, as C D.

Immediately adherent to the sclerotica within, is the

choroides, which is a soft and tender coat, composed of numerous vessels. This membrane is inwardly of a russet-brown colour, inclining to black. Like the sclerotica, it is distinguished into two parts; the fore part is called the iris, while the hinder part retains the name of choroides. The whole of the choroides is opaque, by which means no light is allowed to enter into the eye, but what passes through the pupil.

The third and last membrane of the eye is called the retina, a fine and delicate membrane, being an expansion of the medullary part of the optic nerve. It is spread like a net all over the concave surface of the choroides, and serves to receive the images of objects produced by the refraction of the different humours of the eye, and these objects are painted, as it were, upon its surface. It is itself transparent, but appears black, from the pigmentum nigrum spread underneath it.

From the hinder part of the eye (but not from the centre part) proceeds the optic nerve A, which conveys to the brain the sensations produced upon the retina.

The Humours of the Eye.

3. The coats of the eye A B which invest and support each other after the manner of the concentric coats of an onion, or other bulbous root, inclose three transparent bodies, called the aqueous, crystalline, and vitreous humours.

1. The aqueous humour is the most fluid, being thin and clear like water: it fills up the space between the cornea and ciliary ligament, being divided into two portions by the iris, which swims in it. These are called the anterior and the posterior portions of the aqueous humour.

2. The crystalline is the second humour of the eye, and

is as transparent as the purest crystal; but in consistence it resembles a hard jelly, growing somewhat softer from the middle towards the edges. Its form is that of a double convex lens, but more convex on the interior than on the exterior surface.

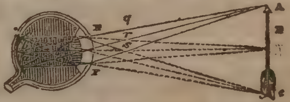
3. The vitreous is the third humour of the eye; and it receives its name like the others, from its appearance, which is like melted glass. It is not so hard as the crystalline, nor so liquid as the aqueous humour. It fills all the interior chamber of the eye, behind the crystalline humour.

Questions for Examination.

1. Describe the eye.
2. Describe the coats of the eye.
3. What are the humours of the eye?

Section VI.

The Manner in which Vision is Performed.



1. Every point of an object, A B C, sends out rays in all directions, therefore some rays from every point on the side next the eye, will fall upon the cornea, between E and F; and by passing on through the humours and pupil of the eye, to as many points on the retina, will thereon form a distinct inverted picture, *c b a*, of the object A B C.

Illus. Thus the pencil of rays, *q r s*, that flow from the point A of the object, will be converged to the point *a* on the retina; those from the point B, will be converged to the point *b*; those from the point C, will be converged to the point *c*; and so of all the intermediate points, by which means the whole image *a b c* is formed, and the object

made visible; although it must be owned, that the method by which this sensation from the eye, by the optic nerve, to the common sensorium in the brain, is there discerned, is above the reach of our conception.

2. *To demonstrate experimentally that Vision is effected in this manner.*

Exp. Take a bullock's eye while it is fresh, and having cut off quite to the vitreous humour, the three coats from the back part, put a piece of white paper over that part, and hold the eye towards any bright object, and you will see an inverted picture of the object upon the paper.

Obs. But inverted is only a relative term; and there is a very great difference between the real object and the means or image by which we perceive it. When all the parts of a distant prospect are painted upon the retina, they are all right with respect to one another, as well as the parts of the prospect itself; and we can only judge of an object's being inverted, when it is turned reverse to its natural position, with respect to other objects which we see and compare it with. If we lay hold of an upright stick in the dark, we can tell which is the upper or lower part of it, by moving our hand upward or downward; and who does not know very well that he can feel the upper end by moving his hand downward? Just so we find by experience, that upon directing our eyes towards a tall object, we cannot see its top by turning our eyes downward, nor its base by turning our eyes upward; but must trace the object the same way by the eye to see it from head to foot, as we do by the hand to feel it; and as the judgment is informed by the motion of the hand in one case, so it is also by the motion of the eye in the other.

Questions for Examination.

1. How is vision performed?
2. How do you demonstrate experimentally that vision is performed as you have described in your last answer?

SECTION VII.

Of Dimness of Sight and Spectacles.

1. Dimness of sight generally attends old people, and it may arise from either of these two causes:

1. By the eyes growing flat, and not uniting the rays at the retina, which causes indistinctness of vision; or,

2. By the opacity of the humours of the eye, which, in time, lose their transparency in some degree; from whence it follows, that a great deal of the light that enters the eye is stopped and lost, and every object appears faint and dim.

2. As the rays of light flowing from an object, and painting its image upon the retina, are the immediate cause of seeing, so where there is no light there can be no vision; consequently, without light the eye becomes a machine totally useless, as it can give us no manner of information of the existence of bodies at a distance from us.

3. Different length of sight in different persons is owing to a more or less convexity of the cornea and crystalline humour of the eye; the rounder these are, the nearer will be the focus or point of the meeting rays, and so much the nearer must an object be brought to see it well.

4. The case of short-sighted people is only an over-roundness of the eye, which makes a very near focus; and that of old people is a sinking or flattening of the eye, whereby the focus is thrown to a great distance; hence the former may properly be called eyes of too short, and the latter

eyes of too long a focus. The remedy for the last is a convex glass, to supply the want of convexity in the eye itself, and bring the rays to a shorter focus; but the first require a concave glass, to scatter the rays, and prevent them coming to a point too soon.

Obs. Old people hold objects which they would examine at a great distance from them, for the reason above mentioned; and short-sighted people cannot distinguish an object without bringing it very near to their eyes. But the short-sighted can distinguish much smaller objects than long-sighted people; for the object is magnified in proportion to the roundness of the eye and the nearness of the focus. Short-sighted people have also this farther advantage, that age improves their eyes by the same means that it impairs other people's, that is, by making them more flat.

Proper Construction of Spectacles.

5. When glasses are put in frames for spectacles, these frames ought not to be straight to place both eyes in the same plane; but they should be so bent in the middle, that the axes of both glasses may be directed to one point, at such a distance as you generally look with spectacles. By this means the eyes will fall perpendicular upon both glasses, and make the object appear distinct: but if they fall obliquely upon the glasses, this obliquity will cause a confused appearance in the objects.

Obs. Spectacles are the most useful of optical machines. There are few people that grow into years but have occa-

sion for them, to help their defective eyes, which, without them, would be useless in a great many occasions of life.

6. The nearer any object can be brought to the eye, the larger will be the angle under which it appears, and the more it will be magnified.

Obs. Now, that distance from the naked eye, where the generality are supposed to see small objects best, is about six inches; consequently, when such objects are brought nearer than this measure, they will become less distinct; and if they are brought to four or three inches, they will scarce be seen at all. But by the help of convex glasses, we are enabled to view things clearly at much shorter distances than these; for it is the nature of the convex lens to render any object distinctly visible to the eye at the distance of its focus; wherefore, the smaller a lens is, and the more its convexity, the nearer is its focus and the more its magnifying power.

Questions for Examination.

1. To what is dimness of sight owing?
2. How do you prove that the eye is useless without light?
3. To what is different lengths of sight owing in different individuals?
4. What is the cause of short sightedness?
5. What is the proper construction of spectacles?
6. How are objects magnified?

Section VIII.

Of Telescopes, Microscopes, &c.

1. Telescopes, in general, represent terrestrial objects to be nearer, but not larger; and this nearness, vicinity, or seeming approach of the object, is as the magnifying power of the telescope. Thus looking at a man one hundred yards off,

with a telescope that magnifies one hundred times, the man will appear to be no bigger, but will seem only to be a yard off, and the like of other objects situated on the earth.

2. Microscopes are instruments for viewing small objects. It was before observed, that Nature has so formed the human eye, that we cannot distinctly view an object at a nearer distance than six inches; and since there is an infinity of objects, which at that distance appear either as points, or are wholly imperceptible, what instrument or contrivance soever that will render such minute objects visible and distinct, we properly call a microscope.

The Magic Lanthorn, and Phantasmagoria.

3. The magic lanthorn is a small machine for amusing children, by magnifying paintings on glass, and throwing their images upon a white screen in a darkened chamber. This instrument is capable of being employed for more important purposes, by using such figures as will explain the principles of Astronomy, Botany, &c.

The Camera Obscura.

5. This optical machine, is used in a darkened chamber, the light comes through a double convex lens, and represents the opposite objects inverted upon any white matter placed in the focus of the glass.

Questions for Examination.

1. What is the use of telescopes?
2. What also is the use of microscopes?
3. What is the use of the magic lanthorn?
4. And what is the use of the camera obscura?

CHAPTER IX.

ACOUSTICS.

SECTION I.

General Principles.

1. Is the science which instructs us in the the nature of sounds; and it is divided by some writers into *diacoustics*, which explain the properties of those sounds that come directly from the sonorous body to the ear, and *catacoustics*, which treat of reflected sounds; but such distinctions are of no real utility.

Illus. 1. Most sounds are conveyed to us on the bosom of air; but whether they float upon it, or are propelled forward in it, certain it is that without this or some other fluid, we should not have any sounds. Let the air be exhausted from a receiver, and a bell shall emit no sound when rung in the void; for as the air continues to grow less dense, the sound dies away in proportion, so that at last its strongest vibrations are almost totally silent. Thus, air is a vehicle for sound. However, we do not assert that it is the only vehicle; that if there were no air we should have no sounds whatsoever; for it is found by experiment, that sounds are conveyed through water with the same facility with which they move through air. A bell rung in the water returns a tone as distinct as if it was rung in air.

2. One thing, however, is certain, that whether the fluid which conveys the note be elastic or non-elastic, whatever sound we hear is produced by a stroke, which the sounding body makes against the fluid, whether air or water. The fluid being struck upon, carries the impression for-

ward to the ear, and there produces its sensations. Philosophers are so far agreed, as to allow that sound is nothing more than the impression made by an elastic body upon the air or water, and this impression carried along by either fluid to the organ of hearing; but then they dispute the manner in which this conveyance is made: whether the sound is diffused into the air in circle beyond circle, like the waves of water when we disturb the smoothness of its surface by dropping in a stone, or whether it travels along like rays diffused from a centre, somewhat in the swift manner that electricity runs along a rod of iron. To us it appears to move in concentric waves.

2. *Of the Velocity, &c. of Sound.*

Axiom 1. By the experiments of some philosophers, it has been proved that sound travels at about the rate of 1142 feet in a second, or near 13 miles in a minute; nor do any obstacles hinder its progress, a contrary wind only a small matter diminishing its velocity.

Example 1. To calculate the progress of sound:—When a gun is discharged, we see the fire long before we hear the sound: if then we know the distance of the place, and know the time of the interval between our first seeing the fire and then hearing the report, this would shew us exactly the time in which the sound has been travelling to us. For instance, if the gun is discharged a mile off, the moment the flash is seen you count on a watch the seconds till you hear the sound, and the number of seconds is the time the sound has been travelling a mile.

2. Again, by the above Axiom, we are enabled to find the distance between objects that would be otherwise immeasurable. For example, suppose that you see the flash of a gun during the night at sea, and tell seven seconds before you hear the report; it follows, therefore, that the dis-

tance is seven times 1142 feet, that is, 24 yards more than a mile and a half.

3. In like manner, if you observe the number of seconds between the lightning and the report of the thunder, you know the distance of the cloud from whence it proceeds.

Axiom 2. Derham has proved by experiments that all sounds whatever travel at the same rate. The sound of a gun and the striking of a hammer are equally swift in their motions; the softest whisper flies as swiftly (as far as it goes) as the loudest thunder.

To these axioms we may add the following:

Axiom 3. Smooth and clear sounds proceed from bodies that are homogeneous, and of an uniform figure; and harsh or obtuse sounds from such as are of mixed matter and irregular figure.

4. The velocity of sounds is to that of a brisk wind as fifty to one.

5. The strength of sounds is greatest in cold and dense air, and least in that which is warm or rarefied.

6. Every point against which the pulses of sound strike becomes a centre, from which a new series of pulses are propagated in every direction.

7. Sound describes equal spaces in equal times.

Questions for Examination.

1. What is acoustics? illustrate this science.

2. How do you prove and illustrate the velocity of sound? and from what do smooth and clear, harsh or obtuse sounds proceed?

SECTION II.

3. *Of Reverberated Sounds.*

Sound, like light, after it has been reflected from several places, may be collected into one point, as into a focus; and it will there be more audible than in any other part, even than at the

place from whence it proceeded. On this principle it is that a whispering gallery is constructed.

The Whispering Gallery.—Fig. 1, *pl.* 2.

Illus. 1. The form of a whispering gallery must be that of a concave hemisphere, as A D C; and if a low sound be uttered at A, the vibrations expanding themselves every way, will impinge on the points D, D, D, &c. and from thence to the points E, F, and G, till at last they all meet in C, where, as we have said, the sound will be most distinctly heard.

Of Speaking Trumpets.—Fig. 2, *plate* 2.

Illus. 2. The augmentation of sounds by means of *speaking trumpets* is usually illustrated in the following manner: let A B C be the tube, B D the axis, and B the mouth-piece for conveying the voice to the tube. Then it is evident when a person speaks at B in the trumpet, the whole force of his voice is spent upon the air contained in the tube, which will be agitated through its whole length, and by various reflections from the side of the tube to the axis, the air along the side will be greatly condensed, and its momentum proportionably increased, so that when it comes to agitate the air at the orifice of the tube A C, its force will be as much greater than what it would have been without the tube, as the surface of a sphere, whose radius is equal to the length of the tube, is greater than the surface of the segement of such a sphere, whose base is the orifice of the tube. For a person speaking at B without the tube will have the force of his voice spent in exciting concentric superficies of air all round the point B; and when those superficies or pulses of air are diffused as far every way as D, it is plain that the whole force of the voice will there be diffused through the whole superficies of a sphere whose radius is B D; but in the trumpet it will be so confined, that at its exit it will be diffused through so much of that spherical surface of air as corresponds to the orifice of the

tube. But since the force is given, its intensity will always be inversely as the number of particles it has to move; and therefore *within* the tube it will be to that *without*, as the superficies of such a sphere is to the area of the larger end of the tube nearly.

Farther, when we speak in the open air, the effect on the tympanum of a distant auditor is produced merely by a single pulse. But when we use a tube, all the pulses propagated from the mouth, except those in the direction of the axis, strike against the sides of the tube, and every point of impulse becoming a mere entry from whence the pulses are propagated in all points, a pulse will arrive at the ear from each of these points; thus, by the use of a tube, a greater number of pulses are propagated to the ear, and consequently the sound increases. The confinement too of the voice, may have a little effect, though not such as is ascribed to it by some; for the condensed pulse produced by the naked voice, freely expands every way; but in tubes, the lateral expansion being diminished, the direct expansion will be increased, and consequently the velocity of the particles and the intensity of the sound.

The substance also of the tube has its effect; for it is found by experiment, that the more elastic the substance of the tube, and consequently the more susceptible it is of these tremulous motions, the stronger is the sound.

If the tube is laid on any non-elastic substance it deadens the sound, because it prevents the vibratory motion of the parts.

The sound is increased in speaking trumpets if the tube be suspended in the air; because the agitations are then carried on without interruption. These tubes should be increased in diameter from the mouth-piece, because the parts vibrating in directions perpendicular to the surface will conspire in impelling forward the particles of air, and consequently, by increasing their velocity, will also increase the intensity of the sound, and the surface also increasing, the number of points of impulse and of new propagation will increase also proportionally.

The several causes, therefore, of the increase of sound in

these tubes, Dr. Young concludes to be, 1. The diminution of the lateral, and, consequently, the direct expansion and velocity of the included air. 2. The increase of the number of pulses, by increasing the points of new propagation. 3. The reflections of the pulses from the tremulous sides of the tube, which impel the particles of air forward, and thus increase their velocity.

Of Echoes.

Illus. 3 *of an echo.* An echo is a reflection of sound striking against some object, as an image is reflected in the glass: but it has been disputed what are the proper qualities in a body for thus reflecting sounds. It is in general known that caverns, grottoes, mountains, and ruined buildings, return this reflection of sound.

We have heard of a very extraordinary echo, at a ruined fortress near *Louvain* in Flanders. If a person sung he heard only his own voice without any repetition: on the contrary, those who stood at some distence heard the echo, but not the voice; but then they heard it with surprising variations, sometimes louder, sometimes softer, now more near, then more distant.

There is an account in the *Memoirs of the French Academy*, of a similar echo near Rouen.

Philosophical Principle of an Echo.—Fig. 3, *pl.* 2.

It has been already observed that every point, against which the pulses of sound strike, becomes the centre of a new series of pulses, and sound describes equal distances in equal times; therefore, when any sound is propagated from a centre, and its pulses strike against a variety of obstacles, if the sum of the right lines drawn from that point to each of the obstacles, and from each obstable to a second point, be equal, then will the latter be a point in which an echo will be heard. Thus, let A be the point from which the sound is propagated in all directions, and let the pulses strike against the obstacles C, D, E, F, G, H, I, &c. each of these points becomes a new centre of pulses by the first principle, and therefore from each of them one

series of pulses will pass through the point B. Now if the several sums of the right lines $\overline{AC+CB}$, $\overline{AD+DB}$, $\overline{AE+EB}$, $\overline{AG+GB}$. AH+HB, AI+IB, &c., be all equal to each other, it is obvious that the pulses propagated from A to these points, and again from these points to B, will all arrive at B, at the same instant according to the second principle; and therefore, if the hearer be in that point, his ear will at the same instant be struck by all these pulses.

Now it appears from experiment that the ear of an exercised musician can only distinguish such sounds as follow one another at the rate of 9 or 10 in a second, or any slower rate; and therefore for a distinct perception of the directed and reflected sound, there should intervene the interval of $\frac{1}{9}$ of a second; but in this time sound describes $\frac{1142}{9}$ or 127 feet nearly. And therefore, unless the sum of the lines drawn from each of the obstacles of the points A and B, exceeds the interval AB by 127 feet, no echo will be heard at B. Since the several sums of the lines drawn from the obstacles to the points A and B are of the same magnitude, it appears that the curve passing through all the points C, D, E, F, G, H, I, &c. will be an *ellipse*. Hence, all the points of the obstacles which produce an echo, must lie in the surface of the oblong spheroid, generated by the revolution of this ellipse round its major axis.

Different Echoes philosophically accounted for.

As there may be several spheroids of different magnitudes, so there may be several different echoes, of the same original sound. And as there may happen to be a greater number of reflecting points in the surface of an exterior spheroid than that of an interior, a second or a third echo may be much more powerful than the first, provided that the superior number of reflecting points, that is, the superior number of reflected pulses propagated to the ear, be more than sufficient to compensate for the decay of sound, which arises from its being propagated through a greater

space. This is finally illustrated in the celebrated echoes at the Lake of Killarney in Ireland, where the first return of the sound is greatly inferior to those which succeed it immediately.

Corol. From what has been laid down, it appears, that, for the most powerful echo, the sounding body should be in one focus of the ellipse, which is the section of the echoing spheroid, and the hearer in the other. However, an echo may be heard in other situations, but not so favourably, as such a number of reflected pulses may arrive at the same time at the ear, as may be sufficient to excite a distinct perception. Thus a person often hears the echo of his own voice; but for this purpose he should stand at least 63 or 64 feet from the reflecting obstacle, according to what has been said before.

At the common rate of speaking, we pronounce not above three syllables and a half, that is seven half syllables in a second, therefore, that the echo may return just as soon as three syllables are expressed, twice the distance of the speaker from the reflecting object must be equal to 1000 feet; for as sound describes 1142 feet in a second, $\frac{6}{7}$ of that space, that is 1000 feet nearly will be described, while six half, or three whole syllables are pronounced; that is the speaker must stand 500 feet from the obstacle. And in general, the distance of the speaker from the echoing surface, for any number of syllables, must be equal to the seventh part of the product of 1142 feet multiplied by that number.

In churches we never hear a distinct echo of the voice, but a confused sound when the speaker utters his words too rapidly; because the greatest difference between the direct and reflected courses of such a number of pulses as would produce a distinct sound, is never in any church equal to 127 feet, the limit of echoes. But though the first reflected pulses may produce no echo, both on account of their being too few in number, and too rapid in their return to the ear; yet it is evident that the reflecting surface may be so formed, as that the pulses which come to the ear after two reflections or more, may after having described 127 feet or more, arrive at the ear in sufficient numbers,

and also so nearly at the same instant, as to produce an echo, although the distance of the reflecting surface from the ear be less than the limit of echoes.

Example. This is confirmed by a singular echo in a grotto on the banks of a little brook called the Dinan, about two miles from Castlecombe, in the county of Kilkenny. As you enter the cave and continue speaking loud, no return of the voice is perceived: but on your arriving at a certain point, which is not above 14 or 15 feet from the reflecting surface, a very distinct echo is heard. Now this echo cannot arise from the first course of pulses that are reflected to the ear, because the breadth of the cave is so small, that they would return too quickly to produce a distinct sensation from that of the original sound It is therefore produced by those pulses, which after having reflected several times from one side of the grotto to the other, and having run over a greater space than 127 feet, arrive at the ear in considerable numbers, and not more distant from each other, in point of time, than the ninth part of a second.

Questions for Examination.

1. What are reverberated sounds? Illustrate the principle of the whispering gallery—Of speaking trumpets—echoes, and account philosophically for these last.

Section III.

Philosophical Acoustic Experiments.

1. *The Conversing Statue.—Fig. 4, pl. 2.*

Description.—Place a concave mirror, about two feet diameter, as A B, in a perpendicular direction. The focus of this mirror may be at 15 or 18 inches from its surface. At the distance of about five or six feet, let there be a partition, in which there is an opening E F, equal to the size of the mirror; against this opening must be

placed a picture, painted in water colours, on a thin cloth that the sound may easily pass through it.

Note. The more effectually to conceal the cause of this illusion, the mirror A B may be fixed in the wainscot, and a gauze, or any other thin covering, thrown over it, as that will not in the least prevent the sound from being reflected. An experiment of this kind may be performed in a field or garden between two hedges, in one of which the mirror A B may be placed, and in the other an opening artfully contrived.

Behind the partition, at the distance of two or three feet, place another mirror G H, of the same size as the former, and let it be diametrically opposite to it.

Note. Both the mirrors here used may be of tin or gilt pasteboard; this experiment not requiring such as are very accurate.

At the point C, let there be placed the figure of a man seated on a pedestal, and let his ear be placed exactly in the focus of the first mirror, his lower jaw must be made to open by a wire, and shut by a spring; and there may be another wire to move the eyes: these wires must pass through the figure, go under the floor, and come up behind the partition.

Let a person, properly instructed, be placed behind the partition near the mirror. You then propose to any one to speak softly to the statue, by putting his mouth to the ear of it, assuring him that it will answer instantly. You then give the signal to the person behind the partition, who by placing his ear to the focus I, of the mirror or G H, will hear distinctly what the other said; and moving the jaws and eyes of the statue by the wires will return an answer directly, which will in like manner be directly heard by the first speaker.

2. *The Communicative Busts.*

Let there be two heads of plaster of Paris,

placed on pedestals on the opposite sides of a room. There must be a tin tube of an inch diameter, that must pass from the ear of one head, through the pedestal, under the floor, and go up to the mouth of the other. Observe that the end of the tube which is next the ear of the one head should be considerably larger than that end which comes to the mouth of the other.

Let the whole be so disposed, that there may not be the least suspicion of a communication. Now when a person speaks quite low, into the ear of one bust, the sound is reverberated through the length of the tube, and will be distinctly heard by any one who shall place his ear to the mouth of the other. It is not necessary that the tube should come to the lips of the bust. If there be two tubes, one going to the ear and the other to the mouth of each head, two persons may converse together by applying their mouth and ear reciprocally to the mouth and ear of the busts; and at the same time other persons that stand in the middle of the chamber between the heads, will not hear any part of their conversation.

3. *The Oracular Head.*

Place a bust on a pedestal in the corner of a room, and let there be two tubes as in the foregoing amusement; one of which must go from the mouth, and the other from the ear of the bust, through the pedestal and the floor to an under apartment.

There may be likewise wires that go from the under jaw and the eyes of the bust, by which they may be easily moved. A person being placed in the under room, and at a signal given applying his ear to one of these tubes, will

hear any question that is asked and immediately reply; moving at the same time by means of the wires, the mouth and eyes of the bust as if the reply came from it.

4. *The Solar Sonata.*

In a large case such as is used for dials and spring clocks, the front of which, or at least the lower part of it, must be of glass, covered on the inside with gauze, let there be placed a barrel organ, which when wound up is prevented from playing, by a catch that takes a toothed wheel at the end of the barrel. To one end of this catch there must be joined a wire, at the end of which there is a flat circle of cork, of the same dimension with the inside of a glass tube in which it is to rise and fall. This tube must communicate with a reservoir that goes across the front part of the bottom of the case, which is to be filled with spirits, such as is used in thermometers, but not coloured, that it may be concealed by the gauze.

This case being placed in the sun, the spirits will be rarified by the heat; and rising in the tube, will lift up the case or trigger, and set the organ in play: which it will continue to do as long as it is kept in the sun; for the spirits cannot run out of the tube, to which the circle is fixed, being prevented from rising beyond a certain point, by a check placed over it.

When the machine is placed against the side of a room on which the sun shines strong, it may constantly remain in the same place if you inclose it in a second case made of thick wood, and placed at a little distance from the other.

When you want it to perform, it will be only necessary to throw open the door of the outer case and expose it to the sun.

But if the machine be moveable, it will perform in all seasons by being placed before the fire; and in the winter it will more readily stop when removed into the cold.

A machine of this sort is said to have been invented by Cornelius Dreble in the last century. What the construction of that was we know not; it might very likely be more complex, but could scarcely answer the intention more readily.

5. *Automaton Harpsichord.*

Under the keys of a common harpsichord, let there be placed a barrel something like that in a chamber organ with stops or pins corresponding to the tunes you would have it play. These stops must be moveable, so that the tunes may be varied at pleasure. From each of the keys let there go a wire perpendicularly down: the ends of these wires must be turned up for about one fourth of an inch. Behind these wires let there be an iron bar to prevent them going too far back. Now, as the barrel turns round, its pins take the ends of the wires, which pulls down the keys and plays the harpsichord. The barrel and wires are to be all inclosed in a case.

In the chimney of the same room where the harpsichord stands, or at least in one adjacent, there must be a smoke jack, from whence comes down a wire or cord, that passing behind the wainscot, adjoining the chimney, goes under the floor, and up one of the legs of the harpsichord, into the case and round a small wheel, fixed on the axis of that first mentioned; there should be pulleys at different distances, behind the wainscot and under the floor, to facilitate the motion of the cord.

This machinery may be applied to any other keyed instrument as well as to chimes, and to many other purposes where a regular continued motion is required.

An instrument of this sort may be considered as perpetual motion according to the vulgar acceptation of the term, for it will never cease going till the fire be extinguished, or some parts of the machinery be worn out.

6. *The Ventosal Symphony.—Fig.* 5, *pl.* 2.

At the top of a summer house or other building, let there be fixed a vane A B, on which is the pinion C, that takes the toothed wheel D, fixed on the axis E F, which at its other end carries the wheel G, that takes the pinion H.

All these wheels and pinions are to be between the roof and ceiling of the building.

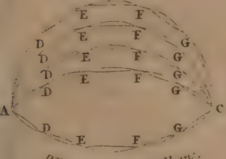
The pinion H is fixed to the perpendicular axis I K, which goes down very near the wall of the room, and may be covered after the same manner as bell wires.

At the lower end of the axis I K, there is a small pinion L, that takes the wheel M, fixed on the axis of the great wheel N O. In this wheel there must be placed a great number of stops, corresponding to the tunes it is to play, and these stops are to be moveable, that the tunes may be altered at pleasure.

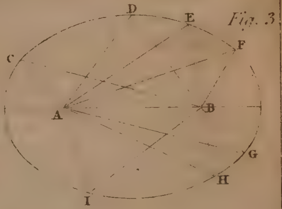
Against this wheel there must hang 12 small bells, answering to the notes of the gamut.

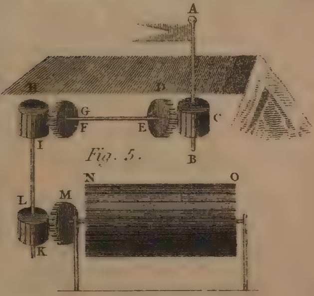
Therefore, as the wheel turns round, the stops striking against the bells, play the several tunes.

Fig. 1.

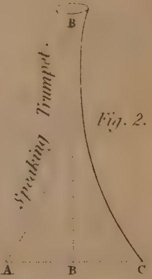


Whispering Gallery.





Ventosal Symphony.



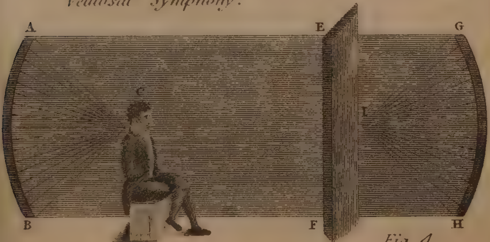


Fig. 4.

Conversing Statue.

Engraved for Pinnock & Maunders Elements of Nat. & Ex. Philosophy by Sid.^y Hall.

There should be a *fly* to the great wheel to regulate its motions, when the wind is strong.

The wheel N O, and the bells are to be inclosed in a case. There may be several sets of bells, one of which may answer to the treble, another to the tenor, and a third to the bass; or they may play different tunes according to the size of the wheel. As the bells are small, if they are of silver their chimes will be the more pleasing.

Instead of bells, glasses may be here used, and so disposed as to move freely at the sound of the stops. This machinery may likewise be applied to a barrel organ; and to many other uses.

Questions for Examination.

1. Describe the construction, and then the amusement of the conversing statue.
2. Describe the construction and amusement of the communicative busts.
3. Also of the oracular head.
4. Of the solar sonata.
5. Of the automaton harpsichord.
6. Of the ventosal symphony.

CHAPTER X.

PNEUMATICS.

SECTION I.

General Principles.

1. PNEUMATICS is the science which treats of the properties of air in general, but more commonly the *mechanical* properties of elastic aeriform fluids, such as their *weight*, *density*, *compressibility*, and *elasticity*. The invisibility of air is only a consequence of its transparency.

2. OF THE ATMOSPHERE. The air is a fluid in which we live and breathe; it entirely envelopes our globe, and extends to a considerable height around it. Together with the clouds and vapours that float in it, it is called the *atmosphere*. As it is possessed of gravity in common with all other fluids, it presses upon bodies in proportion to the depth at which they are immersed in it; and it also presses in every direction, in common with all other fluids.

It differs from all other fluids in the four following particulars :—

1. It can be *compressed* into a much less space than what it naturally possesses.

2. It cannot be *congealed* or fixed as other fluids may.

3. It is of a *different density* in every part upward from the earth's surface, decreasing in its weight, bulk for bulk, the higher it rises.

4. It is of an *elastic* or *springy nature*, and the force of its spring is equal to its weight.

3. Being invisible, and affording no sensible resistance to the touch, it must seem to some people extraordinary to consider air as a solid and material substance, and yet a few simple experiments which may be performed without a regular apparatus will prove that it is really matter, and possesses weight, and has the power of resisting other bodies that press against it.

Experiment 1. Take a *bladder* whose neck is not tied, and you may press the sides together, and squeeze it into any shape. Fill this bladder with air, by blowing into it, and tie a string fast round the neck, you then find that you cannot, without breaking the bladder, press the sides together, and that you can scarcely alter its figure by any pressure. Whence then arise those effects? When the bladder was empty, you could press it into any form; but the air with which it is filled prevents this: the resistance which you experience when it is filled with air, proves that air is as much matter as any other substance with which we are acquainted.

2. We are accustomed to say, that a vessel is empty when we have poured out of it the water which it contained. Throw a *bit of cork upon a basin of water*, and having put an *empty tumbler* over it, with the mouth

downwards force it through the water; the cork will shew the surface of the water within the tumbler, and you will see that within the glass the water will not rise so high as without the glass, nor if you press ever so hard will it rise to the same level. The water is therefore prevented from rising within the tumbler by some other substance which already occupies the inside. This substance is the air that filled the tumbler when it was inverted, and which could not escape, on account of the superior pressure of the water.

3. In like manner, having opened a *pair of common bellows,* stop up the muzzle securely, and you will find that you cannot shut the bellows, which seem to be filled with something that yields a little like wool, but if you unstop the muzzle, the air will be expelled and may be felt against the hand.

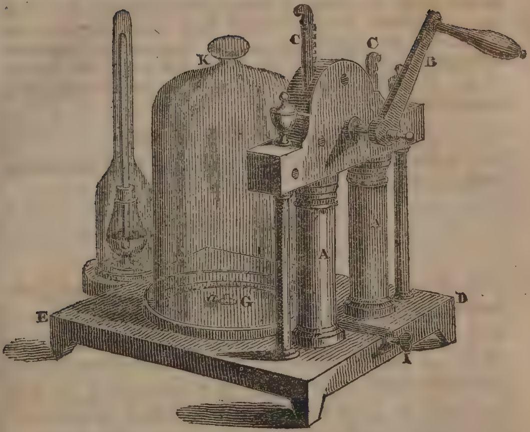
Questions for Examination.

1. Define the science of Pneumatics.
2. What is the atmosphere? How does it differ from all other sorts of fluids?
3. What experiments can you perform in proof of the atmosphere being a substance?

Section II.

The Air Pump.

1. The instrument or machine, by which we ascertain the general mechanical properties of air, is called an *air pump,* the construction and the manner of using which we will describe, before proceeding to the experiments that are made with it.



Description. This diagram exhibits the construction of an air pump that is now commonly used. A A are two brass barrels, each containing a piston, with a valve opening upwards. They are worked by means of the winch B, which has a pinion that fits into the teeth of the racks C C, which are made upon the ends of the pistons, and by this means moves them up and down alternately.

On the square wooden frame D E, there is placed a brass plate G, ground perfectly flat, and also a brass tube let into the wood communicating with the two cylinders and the cock I, and opening into the centre of the brass plate at *a*. The glass vessel K, to be emptied or exhausted of air, has its rim ground quite flat, and rubbed with a little pomatum, or hog's-lard, to make it fit more closely upon the brass plate of the pump. These vessels are called *receivers*. Having shut the cock I, the pistons are worked by the winch, and the air being suffered to

escape when the piston is forced down, because the valve opens upwards, but prevented from returning into the vessel for the same reason, the receiver is gradually exhausted and will then be fixed fast upon the pump plate. By opening the cock I, the air rushes again into the receiver.

Questions for Examination.

1. Describe the air pump. Shew its parts separately and conjointly.

SECTION III.

To ascertain the Weight of Air.

1. To ascertain the weight of air, take a hollow copper ball or other vessel, which holds a wine quart, having a neck to screw on the plate of the air pump, and after weighing it when full of air, exhaust it, and weigh it while empty, it will be found to have lost 16 grains, which shews that this is the weight of a quart of air. But a quart of water weighs 14,621 grains; this divided by 16 gives as a quotient 914, nearly, so that water is 914 times as heavy as air near the surface of the earth.

Obs. When the receiver is placed upon the plate of the air pump without exhausting it, it may be removed again with the utmost facility, because there is a mass of air under it that resists by its elasticity the pressure on the outside; but exhaust the receiver, thus removing the counter pressure, and it will be held down to the plate by the weight of the air upon it.

Questions for Examination.

1. How do you ascertain the weight of the air? How is this proved by the air pump?

SECTION IV.

To determine what the Pressure of Air amounts to.

1. When the surface of a fluid is exposed to the air, it is pressed by the weight of the atmosphere equally on every part, and consequently remains at rest. But if the pressure be removed from any particular part, the fluid must yield in that part, and be forced out of its situation.

Experiment 1.

Into the receiver A, put a small vessel with quicksilver, or any other fluid, and through the collar of leathers at B, suspend a glass tube, closed, or hermetically sealed, as it is called, over the small vessel. Having exhausted the receiver, let down the tube into the quicksilver, which will not rise into the tube as long as the receiver continues empty. But re-admit the air, and the quicksilver will immediately ascend. The reason of this is, that upon exhausting the receiver, the tube is likewise emptied of air, and therefore when it is immersed in the quicksilver, and the air re-admitted into the receiver, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube, consequently it must rise in the tube and continue to do so, until the weight of the elevated quicksilver press as forcibly on that portion which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

Experiment 2.

Take a common syringe of any kind, and having pushed the piston to the farthest end, immerse it into water; the

draw up the piston, and the water will follow it. This is owing to the same cause as the last; when the piston is pulled up, the air is drawn out of the syringe with it, and the pressure of the atmosphere is removed from the part of the water immediately under it, consequently the water is obliged to yield in that part to the pressure on the surface. It is upon this principle, that all those pumps called sucking pumps act; the piston fitting tightly the inside of the barrel, by being raised up, removes the pressure of the atmosphere from that part, and consequently the water is drawn up by the pressure upon the surface.

These effects arising from the weight and pressure of the atmosphere have been absurdly attributed to suction; a word which ought to be exploded, as it conveys a false notion of the cause of these and similar phenomena.

Experiment 3.

To prove that an exhausted receiver is held down by the pressure of the atmosphere, take one open at top, and ground quite flat, as A, and covered with a brass plate B, which has a brass rod passing through it, working in a collar of leather, so as to be air-tight; to this rod suspend a small receiver, within the large one, a little way from the bottom; place the receiver A, upon the pump plate and exhaust it, it will now be fixed fast down; but the small receiver may be pulled up or down with perfect ease, as it is itself exhausted, and all the air which surrounded it removed; consequently it cannot be exposed to any pressure; let then the small one down upon the plate, but not over the hole by which the air is extracted, and re-admit the air into the large receiver, which may then be removed, it will be found that the small one being itself exhausted, is held down fast by the air, which is now admitted round the outside. If the large re-

ceiver be again put over it and exhausted, the small one will be at liberty, and so on, as often as the experiment is repeated.

This effect cannot be accounted for upon any other principle than the pressure of the air ; as the common idea of suction can have nothing to do in the case of the small receiver, which is fixed down merely by letting in the air round it. We ought, therefore, to attribute all those effects, which are vulgarly ascribed to suction, such as the raising of water by pumps &c., to the weight and pressure of the atmosphere.

Experiment 4.

If the top of the receiver be covered by a piece of flat glass, upon exhausting it, the glass will be broken to pieces, by the incumbent weight; and this would happen to the receiver itself, but for the arched top, that resists the weight more than a flat surface.

This experiment may be varied, by tying a piece of wet bladder over the open mouth of the receiver, and leaving it to dry till it becomes as tight as a drum-head. Upon exhausting the receiver, you will perceive the bladder rendered concave, and it will yield more and more, until air striking forcibly against the inside of the receiver, upon being re-admitted again expands it.

Questions for Examination.

1 How do you determine what the pressure of the atmosphere amounts to? Repeat the experiment that proves this with some quicksilver ?

2. How do you illustrate this by another experiment with a common syringe?

3. How do you prove that an exhausted receiver is held down by the pressure of the atmosphere?

4. What effect takes place when the top of the receiver is covered with a piece of flat glass; and what does this prove? How may this experiment be varied?

SECTION V.

Of the Elasticity of Air.

Air is one of the most elastic bodies in nature; that is to say, it is easily compressed into less compass, and when the pressure is removed, it immediately regains its former bulk.

Experiment.

Let murcury be poured into a bent tube A B C D open at both ends, to a small height as B C; then stopping the end D with a cork, or otherwise making it air-tight, measure the length of confined air D C, and pour murcury into the other by A B, till the height above the surface of that in C D be equal to the height at which it stands in the barometer at the time. It is plain then, that the air in the shorter leg will be compressed with a force twice as great as at first, when it possessed the whole space C D: for then it was compressed only with the weight of the atmosphere, but now it is compressed by that weight, and the additional equal weight of a column of mercury. The surface of the mercury will now be at E; and it will be found, upon measuring it, that the space D E, into which the air is now compressed is just half the former C D. If another column of mercury were added, equal to the former, it would be reduced into one-third of the space that it formerly occupied.

Query. How do you prove that the density of the air is proportioned to the force that compresses it?

SECTION VI.

Of the Density of the Atmosphere.

As all the parts of the atmosphere gravitate,

or press upon each other, it is easy to conceive, that the one next the surface of the earth is more compressed and denser than what is at some height above it; in the same manner as if wool were thrown into a deep pit until it reached the bottom. The wool at the bottom having all the weight of what was above it, would be squeezed into a less compass, the layer or stratum above it would not be pressed quite so much; the one above that less still, and so on till the upper one, having no weight over it, would be in its natural state.

This is the case with the air, or atmosphere, that surrounds our earth, and accompanies it in its motion round the sun. On the tops of lofty buildings, but still more on those of mountains, the air is found to be considerably less dense, than at the level of the sea.

Query. How do you prove the density of the atmosphere?

Section VII.

Of the Height of the Atmosphere.

1. The height of the atmosphere has not yet been exactly ascertained, indeed, on account of its great elasticity, it may extend to an immense distance; becoming, however, rarer, in proportion to the distance from the earth.

It is observed that at a greater height than 45 miles, it does not refract the rays of light from the sun; and this is usually considered as the limit of the atmosphere. In a rarer state, however, it may extend much farther, and this is by some thought to be the case, from the appearance of certain meteors which have been reckoned to

be 70 or 80 miles distant, and whose light is thought to depend upon their coming through our atmosphere.

Note. A cubic inch of air as we breathe, would be so much rarefied at the altitude of 500 miles, that it would fill a sphere equal in diameter to the orbit of Saturn.

2. The elastic power of the air is always equivalent to the force which compresses it, for, if it were less it would yield to the pressure, and be more compressed; were it greater, it would not be so much reduced; for action and re-action are always equal; so that the elastic force of any small portion of the air we breathe, is equal to the weight of the incumbent part of the atmosphere, that weight being the force which confines it to the dimensions it possesses.

Illus. To prove this by an experiment, pour quicksilver into the small bath A, and screw the brass collar c of the tube B C into the brass neck of the bottle, and the lower end of the tube will be immersed into the quicksilver, so that the air above the quicksilver in the bottle will be confined there. This tube is open at top, and is covered by the receiver G, and large tube E F, which tube is fixed by brass collars to the receiver, and is closed at top. This preparation being made, exhaust the air out of the receiver G, and its tube, by putting it upon the plate of the air pump, the air will, by the same means be exhausted out of the inner tube B C, through its open top at C. As the receiver and tubes are exhausting, the air that is confined in the glass bottle A, will so press by its spring as to raise the quicksilver in the inner tube to the same height as it stands in the barometer.

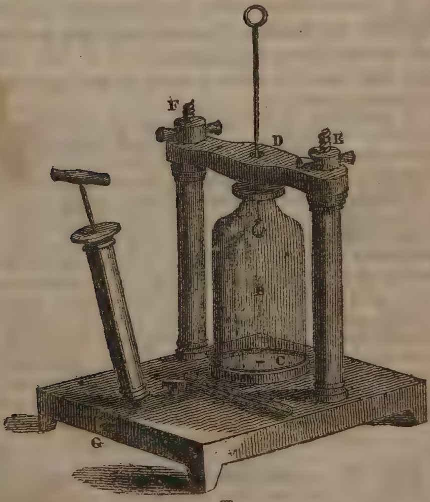
Questions for Examination.

1. Illustrate to what height the atmosphere rises.
2. How do you illustrate the elastic power of air?

SECTION VIII.

Of Condensed Air.

We have shewn, that air can be rarefied, or made to expand; we will now shew that it can also be condensed, or pressed into less space than what it generally occupies. The instrument used for this purpose is called the *condenser*.



Description. This figure represents a machine of this kind; it consists of a brass barrel, containing a piston, which has a valve opening downwards; so that as the piston is raised the air passes through the valve; but as the piston is pushed down, the air cannot return, and is therefore forced through a valve at the bottom of the barrel, that allows it to pass through into the receiver B, but prevents it from returning. Thus, at every stroke of the piston, more air is thrown into the receiver, which is of very thick and strong glass. The receiver is held down upon the plate C by the cross piece D, and the screws, E, F. The air is let out of the receiver by the cock G, which communicates with it.

2. A great variety of experiments may be performed by means of condensed air, a few of which we shall here enumerate.

Exp. The sound of a bell is much louder in condensed than in common air.

2. A phial that would bear the pressure of the common atmosphere, when the air is exhausted from the inside, will be broken by condensing the air round it.

3. A very beautiful fountain may be made by condensed air. Procure a strong copper vessel (Exp. 8) having a tube that screws into the neck of it, so as to be air-tight, and long enough to reach near to the bottom. Having poured a quantity of water into the vessel, but not enough to fill it, and screwed into the tube, adapt to it a condensing syringe, and condense the air in the vessel; shut the stop-cock, and unscrew the syringe, then on opening the stop-cock, the air acting upon the water in the vessel will force it out into a jet of very great height as in Exp. 5. A number of different kinds of jets may be screwed on the tube, such as stars, wheels, &c. forming a very pleasant appearance.

Questions for Examination.

1. How does it appear that air may be condensed?

2. What experiments are you master of to prove the condensation of air?

Section IX.

The Pneumatic Mill.

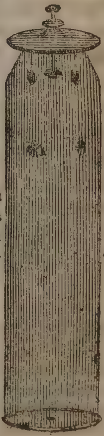
Description. There is a little machine, consisting of two mills, *a* and *b*, of equal weights, and independant of each other, and which turn equally free on their axes on the frame. Each mill has four thin arms or sails fixed into the axis: those of the mill *a*, have their planes at right angles to its axis, and those of *b*, have their planes parallel to it. Therefore, as the mill *a* turns round in common air, it is but little resisted thereby, because its sails cut the air with their thin edges; but the mill *b* is much resisted, because the broad side of its sails, move against the air when it turns round. In each axle is a fine pin near the middle of the frame, which goes quite through the axle, and stands out a little on each side of it: under these pins a slider may be made to bear, and so hinder the mills from going, when a strong spring is set or bent against the opposite ends of the pins.

Experiment I.

Having set this machine upon the pump-plate, draw up the slider to the pins on one side, and set the spring at the opposite ends of the pins: then push down the slider, and the spring acting equally strong upon each mill, sets them both agoing with equal forces and velocities; but the mill *a*, will run much longer than the mill *b*, because the air

makes much less resistance against the edges of its sails, than against the sides of the sails of *b*.

Draw up the slider again, and set the spring upon the pins as before; then cover the machine with the receiver upon the pump-plate; and having exhausted the receiver of air, push down the wire (through the collar of leathers in the neck) upon the slider, which will disengage it from the pins, and allow the mills to turn round by the impulse of the spring: and as there is no air in the receiver to make any sensible resistance against them, they will both move a considerable time longer than they did in the open air; and the moment that one stops, the other will do so too. This shews that air resists bodies, in motion, and that equal bodies meet with different degrees of resistance, according as they present greater or less surfaces to the air.



A

A Feather as heavy as a Guinea.

Experiment 2.

Take a tall receiver A, covered at top by a brass plate, through which works a rod in a collar of leathers, and to the bottom of which there is a particular contrivance for supporting a guinea and a feather, and for letting them stop at the same instant.

If they are let fall while the receiver is full of air, the guinea will fall much quicker than the feather; but if the receiver be first exhausted, it will be found that they both arrive at the bottom at the same instant, which proves that all bodies would fall to the ground with the same velocity, if it were not for the resistance of the air, which impedes most the motion of those bodies that have the least momentum. In this experiment the observer ought not to look at the top, but at the bottom of the receiver, otherwise, on account of the quickness of their motion, he will not be able to see whether the guinea and feather fall at the same instant.

The Silver Shower.

Experiment 3.

Take a receiver, having a brass cap fitted to the top with a hole in it: fit one end of a dry hazel branch about an inch long, tight into the hole, and the other end tight into a hole quite through the bottom of a small wooden cup, then pour some quicksilver into the cup, and exhaust the receiver of air, and the pressure of the outward air on the surface of the quicksilver, will force it through the pores of the hazel, from whence it will descend in a beautiful shower, into a glass cup placed under the receiver to catch it.

Again. Put a wire through the collar of leathers on the

top of the receiver, and fix a bit of dry wood on the end of the wire within the receiver; then exhaust the air, and push the wire down, so as to immerse the wood into a jar of quicksilver on the pump-plate; this done, let in the air, and upon taking the wood out of the jar and splitting it, its pores will be found full of quicksilver, which the force of the air, upon being let into the quicksilver, drove into the wood.

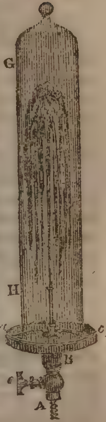
The Pneumatic Sphere.

Experiment 4.

Join the two brass hemispherical cups A and B together, with a wet leather between them, having a hole in the middle of it; then having screwed off the handle at C, screw both the hemispheres, put together, into the pump-plate, and turn the cock E, so that the pipe may be open all the way into the cavity of the hemispheres; then exhaust the air out of them, and turn the cock; unscrew the hemispheres from the pump, and having put on the handle C, let two strong men try to pull the hemispheres assunder by the rings, which they will find hard to do; for if the diameter of the hemisphere be 4 inches, they will be pressed together by the external air with a force equal to 190 pounds; and to shew that it is the pressure of the air that keeps them together, hang them by either of the rings upon the hook of the wire in the receiver A, and upon exhausting the air out of the receiver, they will fall assunder of themselves,

Pneumatic Jet d'Eau.

Experiment 5.



Screw the end A of the brass pipe A B into the pump-plate, and turn the cock *e* until the pipe be open, then put a nut leather on the plate *c d* fixed on the pipe, and cover it with the tall receiver G H, which is close at top, then exhaust the air out of the receiver, and turn the cock *e* to keep it out; which done, unscrew the pipe from the pump, and let its end A into a basin of water, and turn the cock *e* to open the pipe; on which, as there is no air in the receiver, the pressure of the atmosphere on the water in the basin, will drive the water forcibly through the pipe, and make it play up in a jet to the top of the receiver.

To break a Phial on the Pump-plate.

Experiment 6.

Set a square phial upon the pump-plate, and having covered it with a wire cage, put a close receiver over it, and exhaust the air out of the receiver; in doing which the air will also find its way out of the phial through a small valve in its neck. When the air is exhausted, turn the cock below the plate to re-admit the air into the receiver, and as it cannot get into the phial again, because of the valve, the phial will be broken into thousands of pieces by the pressure of the air upon it. Had the phial been of a

round form, it would have sustained this pressure like an arch, without breaking; but as its sides are flat it cannot.

To shew the Elasticity or Spring of the Air.

Experiment 7.

Tie up a small quantity of air in a bladder, and put it under the receiver; then exhaust the air out of the receiver, the air which is confined in the bladder (having nothing to act against it) will expand by the force of its spring, so as to fill the bladder completely. But upon letting the air into the receiver again, it will overpower that in the bladder, and press its sides close together.

If the bladder, so tied up, be put into a wooden box, and have 20 or 30 pounds weight of lead placed upon it, and the box be covered with a close receiver; upon exhausting the air out of the receiver, that which is confined in the bladder will expand itself so as to raise up all the lead by the force of its spring.

Experiment 8.

Screw the pipe A B (see the diagram of Exper. 5) into the pump-plate, place the tall receiver G H upon the plate c d, as before, and exhaust the air out of the receiver; then turn the cock e to keep out the air, unscrew the pipe from the pump, and screw it into the mouth of the copper vessel C, the vessel having been first about half filled with water; then open the cock e, and the spring of the air which is confined in the copper vessel, will force the water up through the pipe A B (see fig. Exp. 5) in a jet into the exhausted receiver, as strongly as it did by its pressure on the surface of the water.

Questions for Examination.

1. Describe the pneumatic mill, and shew what experiments may be performed with it.

2. How do you shew that a small feather, in certain circumstances, is as heavy as a guinea?

3. Describe the experiment of the silver shower.
4. Describe the pneumatic sphere.
5. Also the pneumatic *jet d'eau.*
6. How do you break a phial on the pump-plate?
7. 8. How do you shew the elasticity or spring of air?

SECTION X.

Miscellaneous Experiments.

Experiment 1.

Put a cork into a square phial, and fix it in with wax or cement, and put the phial on the pump-plate with the wire cage, and cover it with a close receiver; then exhaust the air out of the receiver, and the air that was corked up in the phial will break it outwards by the force of its spring, because there is no air left on the outside of the phial to act against that within it.

Experiment 2.

2. Put a shrivelled apple under a close receiver, and exhaust the air; then the spring of the air within the apple will plump it out, so as to cause all the wrinkles to disappear; but upon letting the air into the receiver again, press upon the apple, it will instantly return to its former decayed and shrivelled state.

Experiment 3.

2. Take a fresh egg, and cut off a little of the shell and film from its smallest end, then put the egg under the receiver, and pump out the air; upon which all the contents of the egg will be forced out into the receiver by the expansion of a small bubble of air contained in the great end, between the shell and film.

Experiment 4.

4. Put some warm beer into a glass, and having set it on the pump, cover it with a close receiver, and then exhaust

the air. Whilst this is doing, and thereby the pressure more and more taken off from the beer in the glass, the air therein will expand itself, and rise up in innumerable bubbles to the surface of the beer, and thence it will be taken away with the other air into the receiver. When the receiver is nearly exhausted, the air in the beer, which could not disentangle itself quick enough to get off with the rest, will now expand itself so as to cause the beer to have all the appearance of boiling, and the greatest part of it will go over the glass.

Experiment 5.

Put some water into a glass, and a bit of dry wood, as wainscot, into the water; then cover the glass with a close receiver, and exhaust the air; upon which the air in the wood having liberty to expand itself will come out plentifully, and make all the water bubble about the wood, especially about the ends, because the pores lie lengthways. A cubic inch of dry wainscot has so much air in it, that it will continue bubbling for nearly half an hour.

Experiment 6.

Let a large piece of cork be suspended by a thread at one end of a balance, and counterpoised by a leaden weight, suspended in the same manner at the other end. Let this balance be hung to the inside of the top of a large receiver; which being set on the pump, and the air exhausted, the cork will preponderate, and shew itself to be heavier than the lead, but upon letting in the air again, the equilibrium will be restored. The reason of this is, that since the air is a fluid, and all bodies lose as much of their absolute weight in the air as is equal to the weight of their bulk of the fluid, the cork being the larger body, loses more of its real weight than the lead does, and therefore must in fact be heavier, to balance it under the disadvantage of losing some of its weight, which disadvantage being taken off by removing the air, the bodies then gravi-

tate according to their real quantities of matter, and the cork which balanced the lead in the air, shews itself to be heavier when in vacuo.

Experiment 7.

Set a lighted candle upon the pump, and cover it with a tall receiver. If the receiver holds a gallon of air, the candle will burn a minute, and then having gradually decayed from the first instant, it will go out, which shews that a constant supply of fresh air is as necessary to feed flame, as animal life.

The moment when the candle goes out, the smoke will be seen to ascend to the top of the receiver, and there it will form a sort of cloud; but upon exhausting the air, the smoke will fall down to the bottom of the receiver, and leave it as clear at the top as it was before it was set upon the pump. This shews that smoke does not ascend on ac- on account of its being positively light, but because it is lighter than air; and its falling to the bottom when the air is taken away, shews that it is not destitute of weight. In like manner, many sorts of wood ascend or swim in water; and yet there is nobody who doubts of the wood having gravity or weight.

Experiment 8.

Set a receiver, which is open at top, on the air-pump, and cover it with a brass plate and wet leather, and having exhausted it of air, let the air in again at top through an iron pipe, making it pass through a charcoal flame at the end of the pipe, and when the receiver is full of that air, lift up the cover, and let down a mouse or bird into the receiver, and the burnt air will immediately kill it. If a candle be let down into the air, it will go out directly; but by letting it down gently, it will drive out the impure air, and good air will get in.

Experiment 9.

Set a bell on the pump-plate, having a contrivance so as to ring it at pleasure and cover it with a receiver; then

make the clapper strike against the bell, and the sound will be very well heard; but exhaust the receiver of the air, and then if the clapper be made to strike ever so hard against the bell, it will make no sound; which shews that air is absolutely necessary for the propagation of sound.

Questions for Examination.

1. Describe the experiment of breaking a phial in the exhausted receiver.

2. Also that of expanding or shrevelling a dried-up apple.

3. How do you extract the meat out of an egg with the air pump?

4. What is the experiment performed with some beer in a glass?

5. Also that with a piece of dry wood; what does it shew?

6. What knowledge is derived from the experiment performed with a piece of cork, and a piece of lead?

7. What knowledge is derived from the experiment with a lighted candle?

8. What also from the charcoal flame?

9. How do you prove that air is absolutely necessary for the propagation of sound?

Section XI.

Of the Barometer.

1. Galileo was the first who discovered that it was impossible to raise water higher than 33 feet by suction only. He thence concluded, that, the pressure of the atmosphere was the cause of the ascent of water in pumps; that a column of water 33 feet high was a counterpoise to one as high as the atmosphere, whatever may be the height of this last; and that, for this reason, the water

would not follow the sucker of a pump any farther.

His pupil TORRICELLI considered that as mercury was fourteen times as heavy as water, a column of that fluid need only be one fourteenth of the length of one of water, to form an equal counterpoise to the pressure of the air, and accordingly, having filled with mercury a glass tube about 3 feet long, hermetically sealed at one end, immersed it into a small basin of mercury, and found, as he expected, that the mercury subsided to the height of about 29½ inches, and there remained suspended, leaving a space at the top of the tube, a perfect vacuum, which has been called from the inventor, the *torricelli vacuum.*

It was, however, sometime after this experiment had been made, and even after it had been universally agreed that the suspension of the mercury was owing to the weight of the atmosphere, before it was discovered that the column of mercury varied in height, and consequently, that the pressure of the air was different at different times.

This phenomenon was, however, too remarkable to be long unobserved. It was impossible to avoid observing also, that the changes in the height of the mercury were accompanied or very quickly succeeded by alterations in the weather. Hence the instrument obtained the name of the *weather-glass;* and from its also measuring the weight of the atmosphere, it is called the *barometer,* which is merely a tube filled with mercury, and inverted into a basin of the same, having a scale fixed at the top, to ascertain the rising and falling of the mercury, by the changes in the weight of the atmosphere.

2. There are several modes of constructing and filling the barometer, which it is not our business here to detail. The common construction of the barometer, which is seen in the diagram on page 230, is still found to be the best of any.

The Use of the Barometer.

3. To be best enabled to prognostic the change of weather, accurate observations ought to be made with this instrument, aided by the greatest experience and knowledge of natural philosophy and chemistry; and even then, it would be found that it requires more science than we are possessed of to predict with certainty the alterations of the weather. However, as the barometer undoubtedly affords us considerable assistance, we shall lay down such directions as are most approved of for this purpose.

1. The rising of the mercury presages, in general, fair weather, and its falling, foul weather; as rain, snow, high winds and storms.

2. In hot weather, the falling of the mercury foretells thunder.

3. In winter, the rising presages frost; and in frosty weather if the mercury falls three or four divisions there will certainly follow a thaw. But in a continued frost, if the mercury rise, snow will certainly fall.

4. When foul weather happens soon after the falling of the mercury, expect but little of it; and, on the contrary, expect but little fair weather, when it proves fair shortly after the mercury has risen.

5. In foul weather when the mercury rises much and high, and so continues for two or three days before the foul weather is quite over, then expect a continuance of fair weather to follow.

6. In fair weather, when the mercury falls much and low, and thus continues for two or three days before the

rain comes, then expect a great deal of wet, and probably high winds.

7. The unsettled motion of the mercury denotes uncertain and changeable weather.

8. You are not so strictly to observe the words engraved on the plates (though in general it will agree with them) as the mercury's rising and falling; for if it stand at *much rain* and then rise up to *changeable*, it presages fair weather, though not to continue so long as if the mercury had risen higher; and so, on the contrary, if the mercury stood at fair, and fall to *changeable*, it presages foul weather, though not so much of it as if it had sunk lower.

4. From these observations it appears, that it is not so much the height of the mercury in the tube that indicates the weather, as the motion of it up and down; wherefore, in order to form a right judgment of what weather is to be expected, we ought to know whether the mercury is actually rising or falling; to which end the following rules are of use.

1. If the surface of the murcury be convex, standing higher in the middle of the tube than at the sides, it is generally a sign that the mercury is then rising.

2. If the surface be concave, it is then sinking.

3. If it be level, the mercury is stationary; or rather, if it be a little convex—for mercury being put into a glass tube, especially a small one, will naturally have its surface a little convex, because the particles of mercury attract each other more forcibly than they are attracted by glass. If the glass be small shake the tube; and if the air be grown heavier, the mercury will rise about half the tenth of an inch higher than it stood before; if it be grown lighter it will sink as much. This proceeds from the mercury sticking to the sides of the tube, which prevents the free motion of it until it be disengaged by the shock; and therefore

when an observation is to be made by such a tube, it ought always to be shaken first; for sometimes the mercury will not vary of its own accord, until the weather it ought to have indicated, be present. These phenomena are peculiar to places lying at a considerable distance from the equator,

5. In the torrid zone, the mercury in the barometer seldom either rises or falls much. In Jamaica, it is observed by Sir WILLIAM BEESTON, that the mercury in the morning constantly stood at one degree below changeable, and at noon sunk to one degree above rain; so that in the whole scale of variation there was only three tenths of an inch. At St. Helena, too, where Dr. Halley made his observations, he found the mercury to remain almost stationary, whatever weather happened. Of these phenomena, their causes, and why the barometer indicates an approaching change of weather, the doctor gives us the following account:

1. In calm weather, when the air is inclined to rain, the mercury is commonly low.

2. In serene, good, and settled weather, the mercury is generally high.

3. Upon very great winds, though they be not accompanied with rains, the mercury sinks lowest of all, with relation to the point of the compass the wind blows upon.

4. The greatest heights of the mercury are found upon easterly or north-easterly winds.

5. In calm frosty weather the mercury generally stands high.

6. After very great storms of wind, when the mercury has been very low, it generally rises again very fast.

7. The more northerly places have greater alterations of the barometer, than the more southerly.

8. Within the tropics, and near them, according to the accounts we have had from others, and the observations made at St. Helena, the changes of the weather made very little or no variation in the height of the mercury.

Hence the Doctor conceives that the principal cause of the rise and fall of the mercury, is from the variable winds which are found in the temperate zone, and whose great inconstancy in England is notorious.

A second cause is, the uncertain exhalation and precipitation of the vapours lodging in the air, whereby it is at one time much more crowded than at another, and consequently heavier; but this latter depends in a great measure upon the former. Now from these principles we may explain the several phenomena of the barometer, taking them in the same order as they are laid down. Thus,

1. The mercury being low indicates rain, because the air being light, the vapours are no longer supported thereby, being become specifically heavier than the medium wherein they floated.

2. The greater height of the barometer is occasioned by two contrary winds blowing towards the place of observation.

3. The mercury sinks the lowest of all by the very rapid motion of the air in storms of wind.

4. The mercury stands highest upon the easterly and north-easterly wind.

5. In calm frosty weather the mercury generally stands high, because it seldom freezes but when the winds come out of the northern and north-eastern quarters, or at least unless these winds blow at no great distance off.

6. After great storms, when the mercury has been very low, it generally rises again very fast. It has been observed to rise one inch and a half in less than six hours, after a long continued storm of south-west wind.

7. The variations are greater in the more northerly places, as at Stockholm greater than at Paris.

8. Lastly, this remark, that there is little or no varia-

tion near the equinoctial, does, above all others, confirm the hypothesis of the variable winds being the cause of these variations of the height of the mercury.

Questions for Examination.

1. Describe the invention of the barometer.
2. What kind of this instrument is the best?

3. 4. How does this instrument predict the changes of the weather in places at a considerable distance from the equator.

5. What did Sir William Beeston observe of these changes in the torrid zone?

Section XII.

The Rain Guage.

1. Among other instruments used for observing the state of the weather, we reckon the *hydrometer*—an instrument for measuring the degrees of dryness or dampness of the atmosphere. They are of various constructions. One of the most sensible is that made of the beard of wild oats, which, by twisting, moves an index fastened to it.

2. The *anemoscope* is an instrument for measuring the force of the wind, and the *rain guage* ascertains the quantity of rain that falls in each square foot of the earth's surface.

This figure represents one of the best constructions of rain guages. It consists of a hollow cylinder, having within it a cork ball attached to a wooden stem, which passes through a small opening at the top, on which is placed a large funnel. When this instrument is placed in the open air in a free place, the rain that falls within the circumference of the funnel will run down into the tube, and cause the cork to float, and the quantity of water in the tube may be seen by the height to which the stem of the float is raised. The stem of the float is so graduated as to shew by its divisions the number of perpendicular inches of water which fell on the surface of the earth since the last observation. It is hardly necessary to observe, that after every observation the cylinder must be emptied.

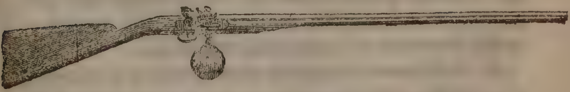
Questions for Examination.

1. What other instruments are used for determining the actual or approaching state of the weather?
2. Describe the rain guage.

Section XIII.

The Air-Gun.

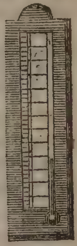
This pneumatical instrument is an ingenious contrivance, which will drive a bullet with great violence, by means of condensed air, forced into an iron ball by a condenser.



The condenser for forcing the air into the ball *b*, at the end *a* of this instument is a male screw, on which the hollow ball *b* is screwed, in order to be filled with condensed air. You then set your feet on the rod *h h*, take the handle *i i* into your hand and pump the ball *b* full of air, which the screw *a* secures till you fasten the ball to the gun for use.

Section XIV.

The Thermometer.



1. The thermometer consists of a bulb of glass, to which is attached a tube filled with alcohol or mercury; and in every thermometer two points are particularly to be attended to—the point at which water freezes, and that at which it boils, called the freezing and boiling points.

2. In Fahrenheit's thermometer, which is that in general use in this country, the scale between these two points is divided into 180 degrees, and as the freezing point is placed at 32° above zero, or 0°, the boiling point is, at 212°, for $180°+32°=212°$. As the exact degree at which water boils is affected by the degree of weight of the atmosphere at the time, the boiling point must be fixed when the air is of a mean weight, indicated by the mercury in the barometer standing at 30 inches.

3. In Reaumur's thermometer, which is in more general use on the continent, the freezing point is

marked 0° or zero, as it ought to be in all thermometers, and there are 80 divisions between that and the boiling point; consequently, every degree of Reaumur's thermometer is equal to $2\frac{1}{4}$ of Fahrenheit's, for $80 \times 2\frac{1}{4} = 180$. When we find, therefore, the heat of the weather given in degrees of Reaumur, we may reduce them to degrees of Fahrenheit by multiplying by $2\frac{1}{4}$, and adding 32°, which is the number above zero where Fahrenheit's freezing point is placed. Thus, if the heat at Vienna be said to be at 20° of Reaumur, $20° \times 2\frac{1}{4} = 45°$, and $45° + 32° = 77°$ of Fahrenheit.

4. In France the thermometer in general use is called the Centigrade, because of its being divided into 100 divisions between the freezing and boiling points, and the freezing point is zero or 0°. This is certainly the most philosophic mode of division. Celsius, a Swedish philosopher, was the first who made use of a thermometer of this sort.

5. To reduce the degrees of the Centigrade thermometer to degrees of Fahrenheit, we must multiply by 9 and divide by 5, and then add 32°, for 100 : 180 :: 5 : 9, or 9 : 5 :: 180 : 100. Thus, suppose the thermometer at Marseilles was at 30°, then $30° \times 9 = 270°$, and $270° \div 5 = 54°$; consequently, $54° + 32° = 86°$ of Fahrenheit.

When Reaumur's, or the Centigrade thermometer, is below zero, it ought to be recollected, in reducing the degrees to those of Fahrenheit, that they are only so many below 32°. Thus, if

Reaumur's stand at —8°, it is the same as 18° below 32°, or 14° of Fahrenheit. If Reaumur's stand at —20°, it is 45° below 32°, or —13° of Fahrenheit.

6. Mercury freezes at 40° below *zero* of Fahrenheit's thermometer, and this degree of cold has been often experienced in Russia, and may easily be produced by freezing mixtures in England.

7. *Experiments with the Thermometer.*

Exper. 1. In the time of snow a freezing mixture may easily be made, by mixing a little snow and common salt in a basin near the fire. If water in an iron cup or phial be put into this mixture, it will immediately be frozen; and if pounded ice and common salt be added, will have a still more powerful effect.

Note. Every time the thermometer is used it ought to be wiped dry after the operation, otherwise it will soon be spoiled.

Obs. The effect of snow in protecting the ground from severe frost may be ascertained by plunging the bulb of the thermometer a considerable way below the surface; the degree of heat will be found greater than that of the air. In the winter, if a thermometer be plunged into water below the ice it will be found warmer than the air. If the thermometer be plunged into melting snow, the degree of heat will be 32° exactly. This will be the case whether it be snow in a basin by the fire-side, or snow on the ground out of doors.

Water in a basin, in which pieces of ice are swimming, will be at 32°; but so soon as the ice is thoroughly melted, the temperature of the water will rise rapidly to that of the room.

Brewers ascertain the state of their liquors in

all their operations by means of a thermometer, and without this instrument all their operations would proceed by guess and risk.

Domestic Uses of the Thermometer.

8. A thermometer is amusing in a room, to enable us to know with accuracy the real degree of heat, as our own feelings are so very deceptive. According to their state of health at the time, different persons will give a different judgment on the subject. After hot weather, a day which is not very cold, will yet feel so to us; and after cold weather we shall be ready to think a day warm, which is not so severe as the preceding.

In winter, a thermometer in a sitting-room enables us to regulate its heat. Too great warmth produced by a fire is injurious to health, as it relaxes the strength, and consumes the pure oxygenous air, so necessary for respiration.

It is not in warm climates that persons affected with pulmonary complaints are most relieved, but in such as that of the island of Madeira, where the sea-breezes abate the summer-heat, and the cold of winter is not felt. Patients who find it impossible to remove to a warmer climate, may greatly benefit themselves by keeping up a regular temperature of about 60° or 62° in their apartments. They thereby escape the dangers of winter, and their complaint is at any rate relieved, and many times may be cured. The same temperature is also the best for persons in full health.

Two experiments will show how differently the feelings of different individuals may be affected by the same degree of heat.

Make one boy go out into the cold air in winter for a

few minutes, and make another sit by a warm fire; then introduce both into a room without a fire; the boy from the cold air will feel it warm, and the other will feel it cold. A much more entertaining experiment will shew, that what will be cold to the one hand will be warm to the other. Pour warm water into one basin, cold water into a second, and a mixture of hot and cold water into a third; then put the one hand into the cold water and the other into warm, for two minutes, and after that put both hands into the luke-warm water, and to the one hand it will feel cold and to the other hot.

Persons ascending from the burning shores of La Vera Cruz, on the road to the mountain land of Mexico, will feel the climate become colder, and will put on their great coats; and yet they will meet people descending who will be complaining of the heat. The same thing occurs in ascending any mountain in a warm country.

9. *Philosophic Experiments.*

The thermometer affords much amusement as well as instruction; a few simple experiments will therefore familiarize the student with its use, and enable him to apply it to more intricate researches.

Exper. 1. If the hand be applied to the bulb of the thermometer, the mercury will rise to about 90°. If the bulb be held in the mouth, or under the arm-pit for a short time, the mercury will rise to 98°.

Obs. This is the heat of the blood when the body is in health, both in summer and winter, in a hot or cold climate. During a fever the heat of the body is greater. In some animals the degree of heat is greater than in man; in others, again, such as frogs and fishes, the blood is much colder; but in all cases, nature fits different animals for their different modes of life.

2. Take a thermometer, which has been some time in a room; observe at what degree the mercury stands, then

plunge the bulb into water that has also been some time in the room. The mercury will neither rise nor fall. Heat has a tendency to pass from one body to another, and, after some time, the sensible heat is equal in all bodies which are near one another.

3. Put a tea-kettle, or saucepan, on the fire with water in it, and, with the thermometer, observe, from time to time, the degree to which the water becomes heated. When boiling, it will be about 212°, and will not rise higher how long soever it may be on the fire.

4. *To ascertain the temperature of a mixture of hot and cold water.* If in the cold water the thermometer stand at 50°, and in the hot water at 130°, in the mixture of both it will stand at 90° for $\frac{50^0 + 130^0}{2} = 90^0$.

5. *To ascertain the temperature of water from a spring or pump,* plunge the thermometer into it, and observe the degree the mercury stands at, which will indicate the temperature of the water. In summer the mercury will sink below the ordinary temperature, because the water is then colder than the temperature of the air. On the other hand, in cold weather, or in winter, though perhaps a little lower than in summer, it will be warmer than the temperature of the air.

Questions for Examination.

1. Describe the thermometer.
2. The construction of Fahrenheit's.
3. Also that of Reaumur's.
4. What is the division of the scale in France?
5. How do you reduce the degrees of the Centigrade or Reaumur's to those of Fahrenheit?
6. At what degree of Fahrenheit does mercury freeze?
7. What experiments may be performed with the thermometer?
8 To what domestic uses is it applied?
9. What philosophical experiments may be performed with the thermometer?

CHAPTER X.

HYDROSTATICS.

Section I.

General Principles.

1. Hydrostatics is the science which treats of the mechanical properties of fluids. Strictly speaking, the weight and equilibrium of fluids at rest, are the objects of this science. When the equilibrium is destroyed, motion ensues; and the science which considers the laws of fluids in motion, is hydraulics.

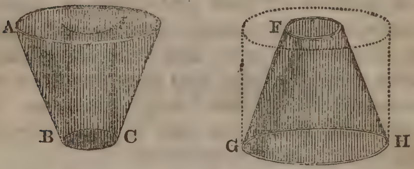
2. A fluid is a body whose parts yield to any impression, and in yielding, are easily moved against each other. Fluids are of two kinds; non-elastic and incompressible fluids, such as water, oil, mercury, &c.: and elastic and compressible fluids, such as *air* of different sorts.

Obs. Modern philosophers suppose, that a certain portion of heat, combined in some way or other with bodies, occasions fluidity, and that the relative portions of heat contained in fluids and solids, is the cause of the difference between them. And it is from the imperfect cohesion of fluids, that, when in small quantities, they arrange themselves in a spherical manner, and form drops.

3. A portion of fluid gravitates in another when surrounded by a larger portion, in the same way as if it were in air. But fluids have this remarkable property, also, that they press not only in common with solids perpendicularly, but also upwards, side ways, and in every direction equally.

Illus. Take a glass tube open at both ends, and stopping one end with your finger, immerge the other in water. The water will be prevented from rising far in the tube by the air which is contained in it, but if you take away your finger from the upper end, the air within the tube will be suffered to escape, and the water will rise in the tube to the same level as it is in the vessel, being pressed upwards by the surrounding water. The same effect will take place, if you incline the tube in any direction; or if you make use of tubes bent in any manner; still you will find that the water within them will rise to the same height as in the external vessel. From this property it is, that if you bore a hole in the side of a vessel filled with water, the fluid will spout out.

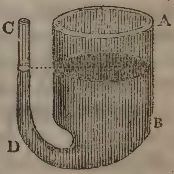
4. A fluid presses in proportion to its perpendicular height, and the base of the vessel containing it, without any regard to the quantity: for as fluids press equally in every direction, the horizontal bottom of a vessel sustains exactly the pressure of a column of fluid, whose base is the area of the bottom of the vessel, and whose perpendicular height is equal to the depth of the fluid.



Illus. Thus, in the vessel A B, the bottom B C sustains a pressure equal to the column whose base is C B, and height C E; and not as the whole quantity of fluid contained in the vessel. Also in the vessel F G, the bottom G H, sustains a pressure equal to what it would be if the vessel were as wide at the top as it is at the bottom.

The Hydrostatic Paradox.

5. What is called the hydrostatical paradox, which the foregoing experiment is the basis of, is this—that a quantity of fluid, how small soever, may be made to counterpoise the greatest quantity.

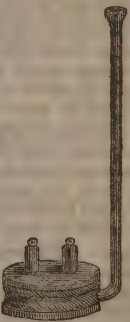


Illus. Thus, if to a wide vessel A B, we attach a tube C D communicating with the vessel, and then pour water into either of them, it will always stand at the same height in both, consequently there is an equilibrium between them. And whatever shape the vessels are of, the effect will be the same This doctrine is of the greatest use in many of the practical affairs of life; for on this principle, as much as the hydraulic principle of fluids of the same mass finding their level, depends the erection of reservoirs, as that on the Castle Hill of Edinburgh, at Islington, at Tottenham Court Road, and the Grand Junction Tower at

Bayswater, the first of which supplies Edinburgh, and the others almost all London with water.

The Hydrostatic Bellows.

6. This instrument is perhaps the best yet invented for demonstrating the upward pressure of fluids.



1. *Construction.* It consists of two thick oval boards, each about 16 inches broad, and 18 inches long, covered with leather, to open and shut like the common bellows, but without valves; only a pipe about three feet high is fixed into the bellows.

2. *Mode of Operation.* If we pour some water into the pipe, it will run into the bellows, separating the boards a little: if we then lay three weights, each weighing 100 pounds, upon the upper board, and pour more water into the pipe, it will run into the bellows, and raise up the board with all the weights upon it; and if the pipe be kept full, until the weights are raised as high as the leather which covers the bellows will allow them, the water will remain in the pipe, and support all the weights, even though the water should weigh no more than a quarter of a pound, and the 300 pounds; nor will this pressure cause the boards to descend, and force the water out at the top of the pipe.

3. *Principle of Action.* The reason of this will appear obvious, if we consider what has been said of the result of the pressure of fluids of equal heights, without any regard to the quantities, as in the hydrostatic paradox. For, if a hole be made in the upper board, and a tube be put into it, the water will rise in the tube to the same height that it does in the pipe, and it would rise as high (by supplying the pipe) in as many tubes as the board would contain holes.

Now, suppose only one hole to be made in the board, of an equal diameter with the bore of the pipe, and that the pipe hold just one quarter of a pound weight of water; if I put my finger upon the hole, and the pipe be filled with water, my finger will be pressed upward with a force equal to a quarter of a pound; and as the same pressure is equal upon all equal parts of the board, each part whose area is equal to the area of the hole, will be pressed upward with a force equal to that of a quarter of a pound: the sum of all these pressures against the under side of an oval board 16 inches broad and 18 inches long, will amount to 300 pounds; and therefore, that much weight will be raised up, and will be supported by a quarter of a pound of water in the pipe.

Hence, if a man stand upon the upper board, and blow into the bellows through the pipe, he will raise himself upward upon the board; and the smaller the bore of the pipe is, the easier will he be able to raise himself. And if he put his finger on the top of the pipe, he may support himself as long as he pleases, provided the bellows be air tight. And upon this principle a press has been constructed, by the help of which hay, straw, wool, and other substances, which are of a light nature, may be forced into small bulk, and be thereby more conveniently taken in large quantities on board of a ship.

Questions for Examination.

1, 2. Define hydrostatics, a fluid, and say of how many kinds fluids are.

3. How does a portion of fluid gravitate, and how press?

4. In what proportion to its perpendicular height does a fluid press.

5. Describe and illustrate the principle of the hydrostatic paradox; and shew its application to conduct pipes and reservoirs.

6. What are the construction, mode of operation, and principle of action of the hydrostatical bellows?

SECTION II.

Of Specific Gravities.

1. By the specific gravities of bodies we mean the relative weights, which equal bulks of different bodies have to each other. And it is usual to compare them with that of water, as it is by weighing bodies in water, that their specific gravities are found.

Obs. 1. The principle of ascertaining the specific gravities of bodies, is due to Archimedes, who discovered it in the following manner :

2. Hiero, king of Syracuse, having given to a workman a quantity of pure gold, of which to make a crown, suspected that the artist had kept part of the gold, and adulterated the crown with a baser metal. The king applied to Archimedes to discover the fraud. The philosopher long studied it in vain, and at length accidentally hit upon a method of verifying the king's suspicion. Going one day into a bath, he took notice that the water rose in the bath, and immediately reflected that any body, of an equa bulk with himself, would have raised the water just as much ; though a body of equal weight, but not of equal bulk, would not raise it so much. From this idea, he conceived a mode of finding out what he so much wished, and was so transported with joy, that he ran out of the bath, stark-naked, crying out in

the Greek tongue, "I have found it, I have found it!"

Illus. Now, since gold was the heaviest of all metals known to Archimedes, it occurred to him that it must be of less bulk, according to its weight, than any other metal, and he, therefore, desired that a mass of pure gold, equally heavy with the crown when weighed in air, should be weighed against it in water, conjecturing that if the crown was not alloyed, it would counterpoise the mass of gold when they were both immersed in water, as well as it did when they were weighed in air. But upon making trial it was found that the mass of gold weighed much heavier in water than the crown did: nor was this all—when the mass and crown were immersed separately in the same vessel of water, the crown raised the water much higher than the mass did; which shewed it to be alloyed with some lighter metal that increased its bulk. And upon this principle is the doctrine of the specific gravities of bodies founded.

3. A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of fluid; but if it be suspended therein, it will loose as much of what it weighed in air, as its bulk of the fluid weighs.

Hence, all bodies of equal bulks, which would sink in fluids, lose equal weights when suspended therein; and unequal bodies lose in proportion to their bulks.

This brings us at once to the illustration of the instrument for finding the specific gravities of fluids, and which is called

The Hydrostatic Balance.

4. *Construction.* It differs very little from a common balance when nicely made; only it has

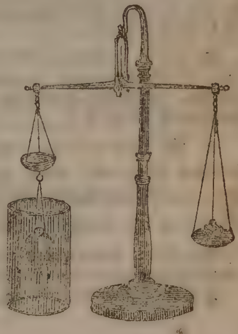
a hook at the bottom of one of the scales, on which different substances that are to be examined may be hung by horse-hairs, or silk threads, so as to be immersed in a vessel of water, without wetting the scale.

Mode of Operation.

If a body, thus suspended under the scale, at one end of the balance, be first counterpoised in air by weights in the opposite scale, and then immersed in water, the equilibrium will be immediately destroyed; if, however, as much weight be put into the scale from which the body hangs, as will restore the equilibrium, without altering the weight in the opposite scale, that weight which restores the equilibrium, will be equal to the weight of a quantity of water as large as the immersed body; and if the weight of the body in air be divided by what it loses in water, the quotient will shew how much that body is heavier than its bulk in water.

Demonstration of the Principle.

A new guinea suspended in air, is counterbalanced by 129 grains in the opposite scale of the balance; upon its being immersed in water, it becomes so much lighter as to require 7¼ grains additional to restore the equilibrium. This shews that a quantity of water of equal bulk with the guinea, weighs 7¼ grains, or 7.25. If now we divide 129 (the weight of the guinea in air) by 7.25, the quotient will be 17.793; which shews that the guinea is 17.793 times as



heavy as its bulk of water. And thus, any piece of gold may be tried, by weighing it first in air, and then in water; and if, upon dividing the weight in air by the loss in water, the quotient comes to be 17.793, the gold is good; if the quotient be 18, or between 18 and 19, the gold is very fine; but if it be less than 17, the gold is too much alloyed with some other metal.

Example 2. I have a guinea which I suspect to be alloyed too much. I weigh it in air; it is 129 grains. I again weigh it in water by the hydrostatic balance: and find it has lost 8.12 grains. What now is its specific gravity? By the foregoing rule the question may be thus stated, *As the loss in water is to the weight in air, so is one to the specific gravity,* therefore as 8.12 : 129 :: 1 : 15.886; for 129 ÷ 8.12 = 15.886 for the specific gravity, shewing the gold is greatly alloyed by baser metal.

Ex. 3. *Of Silver.* If a piece of silver weighs 636 grains in air, what is its specific gravity, supposing it to lose 60.7 when weighed in water? Here 60.7 : 636 :: 1 : 10.470 the specific gravity, by which it appears to be good silver.

Ex. 4. *Of Glass.* How much heavier than water is glass? A piece of white flint glass weighed in air 169.05, and lost in water 50.60. Here 50.60 : 169.05 :: 1 : 3.341; so that it was something more than 3¼ times heavier than its bulk of water.

Ex. 5. *Of Mercury*. One ounce or 4800 grains of mercury weighed in water (in a glass basket) loses nearly 351 grains. Mercury, therefore is heavier than in the proportion of 13.67 to 1.

5. By this method, the specific gravities of all bodies that will sink in water, may be found; first weighing the body in air, then in water, and dividing the weight in air by the loss in water.

But as to those which are lighter than water, as most sorts of wood are, the following method must be taken:

A sort of pincers, or tongs, must be provided, to retain

the substance to be examined, under water. First weigh the body in air, then having balanced the tongs in water, fix to it the body to be weighed, which being lighter than water, will raise the tongs, and cause the other scale to preponderate. Observe the loss of weight of the body in water, and proceed as before.

6. When the specific gravity of any substance is known, it is easy to calculate by the following *table of specific gravities** the weight of any given bulk of that body, as the figures which denote the specific gravity denote also the number of ounces avoirdupois in a solid foot: the figures are now considered whole numbers.

Example 1. *Of Lead.* What is the weight of 7 solid feet of lead? Here, the tabular number for lead is 11.352, which multiplied by 7 gives 79.464; and this divided by 16.28, and 4, gives 46cwt. 1qr. 10lbs. 8oz. for the quotient or weight of 7 solid feet of lead.

Ex. 2. *Of Oak.* What is the weight of 48 solid feet of oak? From the table oak is found to contain 925 ounces in a solid foot; therefore $925 \times 48 \div 16$ by 28 and 4 gives 24cwt. 3qrs. 3lbs. for the weight of 48 feet of solid oak.

Ex. 3. *Of Cork.* What is the weight of 56 solid feet of cork? Here, from the table cork weighs 240 ounces every solid foot; therefore $240 \times 56 \div 16$ by 28 and 4 gives 7cwt. 2qrs. for the answer.

Note. See the table in the next page, 252.

Table of Specific Gravities.

Distilled water	1.000	Limestones from	1.386
Sea water	1.026	——— to	2.390
Crude platina, in grains	15.602	Mercury	13.568
Platina, purified and fused	19.500	Pure silver cast	10.474
——— hammered	20.377	——— hammered	10.511
——— drawn into wire	21.042	Standard silver in coin	10.391
——— laminated	22.069	Lead fused	11.352
Pure gold cast	19.258	Bismuth	9.823
——— hammered	19.362	Nickel	8.660
Standard gold	17.486	Brass, cast	8.396
——— hammered	17.589	—— in wire	8.544
Tin, English, fused	7.291	Cobalt	7.812
——— hammered	7.299	Copper fused	7.788
Mallacca tin, fused	7.296	——— drawn into wire	8.878
——— hammered	7.306	Ponderous spar	4.474
Iron cast	7.207	Flour spar	3.160
—— bar	7.788	Pumice-stone	0.914
Steel, soft, and not hammered	7.840	Green glass	2.620
—— hardened	7.816	English crown glass	2.520
Zinc	7.191	White flint glass, English	3,290
Manganese	6.850	Ditto for achromatic uses	3.437
Antimony	6.702	White glass, French	2.892
Tungsten	6.678	Dry ivory	1.825
Tellurium	6.115	Sulphur	1.990
Molybdena	6.000	Phosphorus	1.714
Arsenic	5.763	Ebony	1.117
Zircon	4.300	Yellow amber	1.078
Barytes	4.200	Common spirit of wine	0.837
Stronthian	3.700	Pure spirit of wine	0.820
Corunda	3.000	Concentrated sulphuric acid	2.125
Silex	2.660	——— nitrous acid	1.580
Magnesia	2.600	——— marine acid	1.194
Lime	2.300	——— fluoric acid	1,500
Alumine	2.000	Oil of olives	0.915
Oriental ruby	4.283	— of sweet almonds	0.917
Garnet	4.188	Linseed oil	0.940
Oriental topaz	4.010	Naptha	0.708
Oriental sapphire	3.994	Gum-elastic	0.393
Emerald of Peru	3.775	Camphor	0.989
Spinel ruby	3.760	Yellow wax	0.965
Diamond	3.521	White ditto	0.959
Rock-Crystal	2.650	Spermaceti	0.943
Agate	2.590	Tallow	0.942
Onyx	2.376	Dry oak	0.925
Muscovy talc	2.792	Dry ash	0.800
Common slate	2.672	Dry maple	0.755
Calcareous spar	2.715	Dry elm	0.600
Alabastic	2.730	Dry fir	0.550
White marble	2.716	Cork	0.240

Note. It appears from the above table that metals hammered, or drawn into wires, have an increased specific gravity.

Questions for Examination.

1. What is meant by specific gravities, and how was the law of specific gravities first discovered?

2. What are the construction, mode of operation, and principle of action of the hydrostatic balance? and shew by examples, how the specific gravities of gold, silver, mercury and lead are found.

3. Also how the specific gravities of those substances which are lighter than water are found, as oak, cork, &c.

SECTION III.

The Hydrometer.

1. The most eligible of all instruments for finding the specific gravity of fluids only, as well for ease as expidition, consists of a copper ball to which is soldered a brass wire, one quarter of an inch thick. The upper part of this wire being filed flat, is marked proof, because it sinks exactly to that mark in proof spirits.

There are other weights to screw on, which shew the specific gravity of different fluids, quite down to common water.

The round part of the wire above the ball, may be marked so as to represent river-water when it sinks to the weight which answers to that water, when that weight has been screwed on. When put into spring-water, mineral water, sea-water, and water of salt springs, it will gradually rise to the marks indicating those waters; on the contrary, when it is put into Bristol-water, rain-water, Port-wine, and mountain-wine, it will successively sink to the marks which denote respectively those liquids. Instruments of this kind are sometimes called acrometers.

Obs. 1. Proof-spirit consists of half water and half pure spirit; that is, such as, when poured on gunpowder, and set on fire, will burn all away; and permit the powder to

take fire and flash, as in open air. But if the spirit be not so highly rectified, there will remain some water, which will make the powder wet, and unfit to take fire. Proof-spirit of any kind weighs seven pounds twelve ounces per gallon.

2. The common method of shaking the spirits in a phial, and raising a head of bubbles, to judge, by their manner of rising or breaking, whether the spirit be proof or near it, is very fallacious. There is no way so certain, and at the same time so easy and expeditious, as by the hydrometer; which infallibly demonstrates the difference of bulks, and, consequently, the specific gravities, in equal weights of spirits, to the fifty-thousandth part of the whole.

2. The improved hydrometer is calculated to ascertain the specific gravity of fluids to the greatest precision possible.

Construction. This instrument consists of a large hollow ball B, with a small bolt *b*, screwed on to its bottom, partly filled with mercury, or small shot, in order to render it but little specifically lighter than water. The large ball has also a short neck at C, into which is screwed the graduated brass wire A C, which, by a small weight at A causes the body of the instrument to descend in the fluid with part of the stem.

3. *Principle of Action.*

When this instrument is swimming in a liquor contained in the jar I L, the part of the fluid displaced by it, will be equal in bulk to the part of

the instrument under the liquor, and equal in weight to the whole instrument.

Now, suppose the weight of the whole to be 4000 grains, it is evident that we can by this means compare the different dimensions of 4000 grains of different sorts of fluids; for if the weight at A, be such as will cause the ball to sink in rain-water, until its surface come to the middle point of the stem 20; and after that, if it be immersed in common spring-water, and the surface be observed to stand at one-tenth of an inch below the middle point 20, it is apparent that the same weight of each water differs only in bulk, by the magnitude of one-tenth of an inch in the stem.

If the stem be ten inches long, and weigh 100 grains, every tenth of an inch will weigh one grain; and as the stem is of brass, which from the table we find is about eight times heavier than water, the same bulk of water will be equal to one-eighth of a grain, and consequently to one-eighth of $\frac{1}{4000}$ part; that is to say, to $\frac{1}{32000}$ part of the whole bulk.

4. In trying the strength of spirituous liquors, a common cylindrical stem does best, because of its strength and steadiness.

Illus. This ought to be so contrived, that, when immersed in what is called proof-spirit, the surface of the spirit may be upon the middle point 20; which is easily done, by duly adjusting the small weight A on the top, and making the stem of such a length, that when immersed in water it may just cover the ball, and rise to its proper height; but when immersed in pure spirit, it may rise to the top A. Then by dividing the upper and lower parts A 20 and *a* 20, into ten equal parts each, when the instrument is immersed in any sort of spirituous liquor, it will immediately shew how much it is above or below proof.

Questions for Examination.

1. Describe and illustrate the principle of the hydrometer.

2. What is the construction of the improved hydrometer?
3. What is its principle of action?
4. What instrument does best in trying the strength of spirits?

SECTION IV.

Of Air-Balloons.

1. The air-baloon is an hydrostatic machine, that consists of a bag filled with air, so light, that the whole is specifically lighter than the common air of the atmosphere. It is in fact, a vessel filled with a fluid which will float in another fluid—air in air.

Illus. A cubic foot of common air is found to weigh above 554 grains, and may be expanded about one-fiftieth part of the whole.

Consequently, by heating a quantity of air, to 200 degrees of Fahrenheit, its bulk will be doubled, when the thermometer stands at 54 in the open air, and in the same proportion, its weight will be diminished.

If therefore such a quantity of this hot air be enclosed in a bag, that the excess of the weight of an equal bulk of common air, weighs more than the bag with the air contained in it, both the bag and the air will rise into the atmosphere, and continue to do so till they arrive at a region where the external air is so much rarefied, that the weight becomes equal. In this region the whole will be suspended.

2. *Experiment.*

To show the power by which hot air is impelled upwards. Roll up a sheet of paper in a conical form, and thrust a pin into it near the apex, to keep it in that form.

By means of a thread fasten it then by its apex, under one of the scales of a balance, and having properly counterpoised it by weights put into the opposite scale, apply the flame of a candle underneath, and you will instantly see the cone rise; and it will not be brought into equilibrium

with the other, but by a much greater weight put into the scale to which it is suspended, than those who have never seen the experiment would believe necessary.

3. *There are two kinds of balloons;* those raised with rarefied, and those filled with inflammable air. And the best forms for balloons are of a globe, and an egg-like figure, as shewn in the engraving.

Fire-ballons, or those raised by heated air, if very large, may be made of linen, or silk, and must be open at bottom, having a hoop round the opening, from which is suspended the grate for the fuel, which is best of straw, or other light combustibles.

4. Large balloons for inflammable air, must be made of silk, and varnished over, so as to be air-tight, as those in the plate.

5. The car, or boat of a balloon, is made of wicker work covered with leather, and well varnished, or painted, and is suspended by ropes proceeding from the net which goes over the balloon. See the engraving.

6. The inflammable air for filling the balloon, is procured by putting a quantity of iron-filings, or turnings, with some oil of vitriol diluted with water, into casks lined with lead. From the top of these casks tin tubes proceed, which unite into one that is connected with the silk tube of the balloon, as seen in the plate.

Balloons cannot be made smaller than five or six feet in diameter, of oiled silk, as the weight of the material is too great for the air to buoy it up.

They may be made smaller of thin stripes of bladder, or other membrane, glued together.

So, on the shoreless air the intrepid Gaul*
Launch'd the vast concave of his buoyant ball;
Journeying on high the silken castle glides,
Bright as a meteor, through the azure tides;
O'er towns, and tow'rs, and temples wends its way,
Or mounts sublime, and gilds the vault of day.
Silent, with upturn'd eyes, unbreathing crowds
Pursue the floating wonder to the clouds:
And flush'd with transport, or benumb'd with fear,
Watch, as it rises, the diminish'd sphere.
Now less and less!—and now a speck is seen!
And now the fleeting rack intrudes between!
The calm philosopher in æther sails,
Views broader stars, and breathes in purer gales;
Sees, like a map, in many a waving line
Round earth's blue plains her lucid waters shine;
Sees at his feet the forked lightnings glow,
And hears the harmless thunders roar below.

DARWIN.

Questions for Examination.

1. What is the air balloon? and on what principle does it float in the air.
2. How do you prove the power by which hot air is impelled upward?
3. How many kinds of balloons are there? and how may each kind be made?
4. Of what must large balloons be made?
5. What is the car or boat?
6. How are balloons filled and kept aloft in air?

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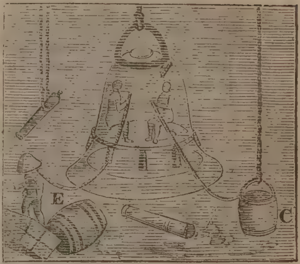
* PILATRE DE ROZIER, the first aërial adventurer, who ascended on the 15th of October, 1783, from the garden of the Fauxbourg Saint Antoine, at Paris.—ED.

Section V.

Of the Diving Bell.

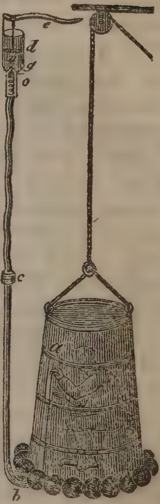
1. The principle of this pnuematic machine, may be illustrated thus: Take a glass tumbler, plunge it in water with the mouth downwards; very little water will rise in the tumbler, as the air which is in the tumbler



prevents the entrance of the water; but as air is compressible, it could not entirely exclude the water, which by its pressure, condensed the air a little.

2. Mr. Smeaton's diving-bell was a square chest of cast iron $4\frac{1}{2}$ feet in height, $4\frac{1}{2}$ feet in length, and 3 feet wide, and afforded room for two men to work in it. It was supplied with fresh air by a forcing pump as you see in the diagram, though the bell be circular, not square, as was Smeaton's. This was used with great success at Ramsgate. Other contrivances have been used for diving to small depths, which have answered very well, such as strong cases for the body, to keep off the pressure of the water, which were supplied by fresh air by pipes from the surface. A very good one of this kind is particularly described in the 8th volume of the Philosophical Magazine.

The first diving bell of any note, was made by Dr. Halley. And a machine of this kind was in the reign of James II. employed to great advantage by Captain Phipps, of New England, who went to the West Indies, and brought up, by means of it, the gold and silver which had sunk in a Spanish treasure ship. Bullion and coins to the amount of £300,000 value were brought to England. The Duke of Albermarle gained £90,000 by the adventure. It has often been used in getting up the goods from a vessel which has sunk in deep water, such as the Abergavenny East Indiaman, which went down near the land in the English Chanel, in 1806. In road-steads, harbours, or docks, it is extremely serviceable in bringing up cannon, anchors, &c. It has also been of use in the blowing up of sunk rocks, which have impeded navigation. See the diagram.



In the diagram you see a man supplied with fresh air by the pipe *a b c*, which is forced into it by the pump *c d g n o*.

But it is observed that the common shape of bells seems the better calculated for any instrument of this name, to sustain the pressure of the surrounding fluid.

Questions for Examination.

1. Describe the principle of the diving-bell.
2. What is said of Dr. Halley's diving-bell? And how was it employed by Captain Phipps, and the Duke of Albermarle?
3. What is said of the diving-bell that Mr. Smeaton used at Ramsgate.

CHAPTER XII.

HYDRAULICS.

Section I.

General Principles.

1. The science of hydraulics teaches us the method of estimating the swiftness and force of fluids in motion.

2. The pressure of water against the sides of vessels is increased by an increase of depth: this holds true, of water in vessels, canals, rivers, reservoirs, &c. and the proportion is as the square of the depth.

Upon the principles of this science many machines worked by water are constructed; and several different engines used in the mechanical arts, various kinds of mills, pumps and fountains, are but applications of this theory judiciously applied.

Illus. Thus, if water at 1 inch depth press with a certain degree of force against the lower part of a cask, and if the depth be increased to 4 inches, the pressure will be twice as much, that is to say, four times the other; if the depth be 9 inches, the pressure will be 3 times as much, that is 9 times the first: if 16 inches, 4 times; if 25 inches 5 times, and so on; the proportion in all cases being as the square of the depth. Hence it appears, that if the quantity of water be great and the depth considerable, the

lower part of whatever incloses it ought to be made increasingly strong towards the lower part.

PROBLEM I.

To prove the velocity with which Water spouts out at a hole in the side or bottom of a Vessel.

3. The velocity with which water spouts out at a hole in the side or bottom of a vessel is, in the foregoing proportion, as the square root of the depth or distance of the hole below the surface of the water: for, in order to make double the quantity of fluid run through one hole as through another of the same size, it will require four times the pressure of the other, and therefore the aperture must be 4 times the depth of the other below the surface of the water; and for the same reason 3 times the quantity running in an equal time through the same sort of hole, must run with 3 times the velocity, which will require 9 times the pressure, and consequently the hole must be nine times as deep below the surface of the fluid, and so on.

Example 1. Take a bucket or cask and make a hole in the lower part of it, and mark at the side by means of any scale of equal parts, the height of one inch, 4 inches, 9 inches, 16 and 25 inches. Fill the bucket or cask as high with water as 25 inches, and notice exactly, when the water is running out, how long it takes to sink as low as 16 inches, it will require exactly the same time to sink from 16 to 9 inches, from 9 to 4, and from 4 to 1, and from 1 till the whole water is run out.

Obs. It was upon this principle that Cæsar constructed his Clypsedra, or water clock, which he mentions as having used to measure time in his expedition to Britain.

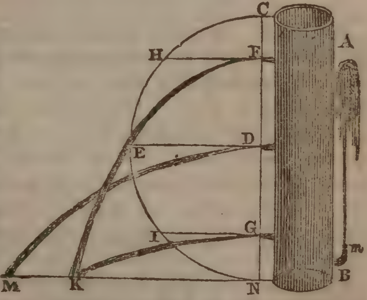
Example 2. Let there be two pipes of equal sized bores fixed into the side of a vessel, one pipe being four times as deep below the surface of the water in the vessel, as the other is: and whilst the pipes run, let water be poured constantly into the vessel, to keep it always full. Then, if a cup that holds a pint be placed to receive the water that

spouts from the upper pipe, and at the same moment a cup that holds a quart be placed to receive the water from the lower pipe, both cups will be filled at the same time by their respective pipes.

PROBLEM II.

To shew the horizontal distance to which a fluid will spout from a horizontal pipe in any part of the side of an upright vessel below the surface of the fluid.

4. This distance is equal to twice the length of a perpendicular to the side of a vessel, drawn from the mouth of a pipe to a semicircle, described upon the altitude of the fluid: and therefore the spout will be to the greatest distance possible from a pipe at the centre of the semicircle: because a perpendicular to its diameter drawn from that point is the longest that can possibly be drawn from any part of the diameter to the semicircle.



Dem. If the vessel A B be full of water, the horizontal pipe D be in the middle of its side, and the semicircle N E C be described upon D as a centre with the radius D C, or D N, the perpendicular D E to the diameter C D N, is the longest line that can be drawn from any part of the diameter to the circumference:

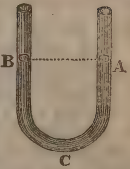
and now if the vessel be kept full, the jet will spout from the pipe D to the horizontal distance M N, which is double the length of the perpendicular D E. If again two other pipes, as F and G, be fixed into the side of the vessel, at equal distances above and below the pipe D, the perpendiculars F H and G I, from these pipes to the semicircle will be equal; and the jets spouting from them will each go the horizontal distance N K, which distance is double the length of either of the perpendiculars F H or G I, and the curves described by the spouting fluid in all the different situations will be portions of a parabola, being acted upon by the combined forces of the lateral pressure of the fluid in the vessel and the force of gravity.

Problem III.

To Level and lay down Pipes for the Conveyance of Water.

5. Fluids by their pressure are conveyed over hills and vallies in bended pipes to any height, not greater than the level of the springs from whence they flow. Of this the ancients were ignorant, and therefore they usually built aqueducts, those vast rows of arches, one above another, between two hills, in order to convey water over vallies, of which we read in history, and some of which remain to this day.

Obs. This is now done to equal advantage, and at much less expence, by a range of pipes laid over hill and valley and may be thus demonstrated:



Demons. If water be poured into one of the legs of the bended pipe B C A it will rise to the same level in the other. The reason is obvious: suppose that in the leg A two ounces of water are endeavouring by the force of gravity to descend with the force of two; this water will thrust forward, buoy up, and support an equal quantity of a like fluid in B; and the bottom of the pipe C, against which both sides equally bear, will of consequence sustain a double pressure, namely, four ounces. So that the rise of fluids to their first level, and all their motions proceed from weight added.

Questions for Examination.

1. Define hydraulics, and illustrate the use of this science.
2. What is the proportion in which fluids press against the bodies which contain them?
3. How do you prove the velocity of fluids?
4. How do you shew the horizontal distance to which a fluid will spout.
5. How are fluids conducted over hills and vallies?

SECTION II.

Hydraulic Machines.

I *The Syphon*

Is generally use in decanting liquors. It is a bended pipe, whose legs are of unequal lengths, as A B.

This useful and simple hydraulic instrument may be thus illustrated:

If a small bent tube, with legs of equal length, be filled with water and turned downwards, the fluid will not run off, but remain suspended therein so long as it is held exactly level; but when either leg is inclined, whereby the perpendicular altidude of one is in effect made shorter than the other, the water will flow from the lowest leg; and will continue to run till the vessel is emptied.

2. *The principle of this theory is as follows:*

The air is a fluid, whose density near the surface of the earth is experimentally found to be to that of water at a medium, as 1 to 914; so that 914 gallons of air near the earth, weigh as much as one gallon of water.

And since the air presses the surface of all things exposed to it every way equally, when, therefore, the legs of the syphon equal in length, are turned down, the weight of the atmosphere above being kept off by the machine, the under air bearing against and repressing the water which tends to fall out of both of them with equal force keeps it in suspension, and prevents its motion; but when, by inclining it to either side, we in effect shorten one of its legs, and lengthen the other in perpendicular altitude, the balance is destroyed, and the longest will preponderate, and the weight of the water in the one overbalances that in the other, and begins to flow.

On this account in practice, one of the legs of the syphon is made longer than the other, that the effect may take place without inclining the instrument.

3. *To make a Syphon act.*

First fill both legs full of the fluid, then place the shorter leg in the vessel to be emptied, and immediately upon withdrawing the finger from the longer leg the liquor will flow.

Obs. If the perpendicular height of a syphon from the

surface of the water to its bended top, be more than 33 feet, it will draw no water, even though the other leg were much longer and the syphon quite emptied of air; because the weight of the column of water 33 feet high, is equal to the weight of a column of air reaching from the surface of the earth to the top of the atmosphere. Mercury may be drawn through a syphon in the same manner as water; but then the utmost height of the syphon must always be less than 30 inches, as mercury is nearly 14 times heavier than water. The syphon may be filled, as we have said, by pouring some of the fluid into it, or by placing the shorter leg in the vessel, and sucking the liquor through the longer leg. Some are made with a sucking pipe attached to the longer leg, and a stop cock. Syphons are extremely convenient for decanting liquors of various kinds, because they do not disturb the sediment.

4. *To illustrate the principle of intermitting and reciprocating Springs.*

4. Upon the principle of the syphon, also, we may easily account for *intermitting or reciprocating springs;* for let A be part of a hill, within which there is a cavity B B, and from this cavity a vein or channel running in an irregular direction B C D, the rain that falls upon the side upon the hill will sink and strain through the small pores and crevices in the hill, and fill the cavity B B with water; when the water rises to the level of C, it will fill all the vein B C D and run through it as a syphon and will empty the cavity B B. It must then stop, and when the cavity is again filled, it will begin to run again.

Questions for Examination.

1. Describe the syphon.
2. What is the principle of the theory on which the syphon acts?
3. How do you make a syphon act?
4. How do you from thence illustrate the principle of intermitting and reciprocating springs?

SECTION III.

Pumps.

1. The pump is a common but useful hydraulic engine. There are three kinds of pumps, viz. the sucking, the lifting, and the forcing pump which we will now explain.

By the two last, water may be now raised to any height with an adequate apparatus and sufficient power; by the sucking pump it can only be raised 33 feet above the surface of the water.

The Sucking Pump.

2. The sucking pump, consists of a pipe, A B, open at both ends, in which is a moveable cylinder or piston, C, the bore of the pipe is that part wherein it works; the piston is so contrived by leathers or other means to fit the bore exactly so as not to allow any air to pass between it and the sides of the pump where it acts. In the piston of this there is a valve opening upwards like a trap door, to allow the air and water readily to ascend through it, but to prevent either of them from descending.

This piston is then called the bucket, and is moved up and down in the pipe by a rod fastened to a handle or lever, or such parts of machinery as are intended to work the pump. The pipe usually consists of two parts of which the first and wider part A D is called the barrel, or working-barrel, because it contains the piston; and the other D B is called the suction-pipe, being of a smaller diameter.

At the joining of the working barrel with the suction-pipe, there is a fixed valve D, opening also upwards. Lastly, the lower end of the suction-pipe is immersed in water, which is admitted into it through small holes as at B, to prevent the entrance of dirt; and at the top of the working-barrel is a wide head, and a pipe E, for the delivery of the water which is raised by the valves and the pressure of the air on the water.

Its mode of operation. When the piston C is close down upon the fixed valve D, both valves remain shut by their own weight; or, which is the same thing, if there be no water in the pump, forcing down C, the valve D is shut, the air having escaped at the valve C, the air above C valve presses it down. Suppose we now want to raise water in this pump: at the beginning of the operation, if the leathers be dry, the piston C will not exhaust the air sufficiently, and the water will not rise; but if a little water be poured upon the piston, it will swell the leathers, and causing them to fit close the piston will thus act. This is vulgarly called *fetching* the water.

Draw the bucket C up from D to C, it is evident that as

it fills the pipe exactly, a vacuum will be formed in that part, therefore the air in the rest of the pipe under the piston will open the fixed valve D, and fill the part which had been exhausted; but it will be rendered less than before; consequently, its opening not being equivalent to the pressure of the atmosphere upon the water in which the pump is immersed, the water will be thence forced up into the *suction* pipe until the air within it is as dense as before, and then it will stop; upon the depressing the piston C a second time, the same effect will be repeated, till at last the water lifts the valve D and comes into the barrel. When the piston now descends, it is forced through the water which cannot be forced through the valve D, because it opens downwards only; the water, therefore, gets above the piston by passing through its valve C, and when it is next raised all the water above it will be lifted up and will be run off by the pipe E.

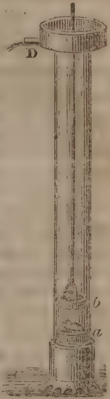
Thus, by alternately raising and depressing the pistons, the effect is produced every time the bucket is raised, the valve D rises and the valve C falls; and at every time the bucket is depressed the valve D falls and C rises; and thus a stream will be produced in some degree continual, but very unequal.

In point of friction, of coolness, and of cheapness, the sucking pump has so evidently the advantage over the chain pump, that it will not fail to gain the preference, whenever it shall be no longer liable to be choaked with gravel, &c.

4. *The Lifting Pump*

Consists of a body or barrel, A B, with narrow apertures at the lower end to prevent the entrance of dirt, stones or any thing that would impede its operation. At the lower end is a valve *a* opening upwards, and allowing the water to

pass through it, but preventing it from returning downwards.



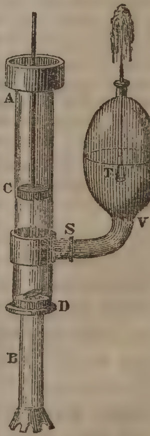
In the barrel is a piston *b*, perforated and having a valve also opening upwards. This piston is moved up and down by a rod, worked by a lever, or other machine; both the piston and the lower valve, must be under the surface of the water in the well. When the piston is pushed down, the water below it not being able to go downwards on account of the valve *a*, raises the valve of the piston and gets above it; and as the piston is drawn up it lifts all the water above it, while the pressure of the atmosphere causes more water to supply its place by lifting the valve *a*. When the piston is moved down again, the same thing is repeated and more water gets above the piston. In this manner by successive motions of the piston, the water is at last got to the top and discharged, into the head, from whence it returns out by the spout D.

In this pump there is always a column of water lifted, whose base is equal to the top of the piston, and whose height is equal to the distance from the piston to the head. It is evident that this weight will not be made less by diminishing the diameter of the barrel above the piston, because fluids press in proportion to their bases and perpendicular altitudes.

This pump is much used in great water-works; it is the simplest of all in its operations.

5. *The Forcing Pump*

Consists of a barrel, A B, and a piston or forcer C. There are also two fixed valves in this kind of pump; one in some convenient part of the sucking pipe as at D, the other in the branching or forcing pipe, as S. These ought in like manner to be air-tight, and so disposed, as to let the water freely rise, but absolutely to hinder its return.



When the forcer is first moved upwards in the barrel, the air between that and the water below, having room to dilate by its natural spring, will of course be rarefied, the pressure of the atmosphere being intercepted by the force of the barrel, A B, on one hand, and by the upper valve at S, in the branching pipe on the other, the water will rise into A B, for the reason already given; and repeated strokes of the piston will fetch up the fluid to the forcer, and fill up the cavity of the pipes between the fixed valves D and S.

The water in this manner raised, being hindered from going down again by the lower valve, will be pressed by the forcer every time it descends, and be thereby obliged to make its way where there is least resistance, viz. through the upper valve at S. And whenever, on the rising of the forcer, this pressure intermits, the valve at S, will immediately close under the weight of the upper water, and prevent its return that way, while the piston is rising with a fresh supply; and this is repeated at every stroke of the forcer. It is evident that the operation of a pump is by

starts, and that the water in the main pipe remains at rest, pressing on the valve during the time, that the piston is withdrawn from the bottom of the working barrel. It is in most cases desirable to have this motion equable, and in some cases it is absolutely necessary.

Thus, in the engine for extinguishing fires, the spout of water going by jerks could never be directed with a certain aim, and half the water would be lost by the way; because a body at rest cannot in an instant be put in rapid motion; and the first portion of every jerk of the water, would have but little velocity. A very ingenious contrivance has been fallen upon, for obviating this inconvenience, and procuring a stream nearly equable. At any convenient part of the rising-pipe beyond the valve S there is annexed a strong and capacious vessel V, closed at top by a small pipe, T, fixed into it, which reaches nearly to the bottom of the vessel. When the water is forced along the rising pipe S, it gets into this vessel and rises above the lower part of the pipe T. The air which is above the water in the vessel, being now confined, and being condensed, into a smaller space, by the admission of more water at each action of the piston, pressed by its elasticity upon the surface of the water, which cannot return by the valve S, forces it up the pipe T, in a continued stream. This air vessel must be so large, that the charge of bulk of the compressed air, during the inaction of the piston, may be inconsiderable, otherwise the stream will not continue until the next stroke. We must not imagine that because the stream produced by the assistance of one air vessel is almost perfectly equable, and because as much water runs out during the returning of the piston, as during its active stroke, that it therefore doubles the quantity of water. No more water can run out than what is sent forward by the piston during its effective stroke. The continued stream is produced only by preventing the whole of this water from being discharged during this time, and by providing a propelling force to act during the piston's return. It is, however, a matter of fact, that a pump furnished with

an air-vessel, delivers little more water than it would do without it.

6. *The Chain Pump*

Consists of two square, or cylindrical barrels, through which a chain passes, having a great number of flat pistons, or valves, fixed upon it at proper distances.

This chain passes round a kind of wheel-work, fixed at one end of the machine. The teeth of this wheel work are so contrived as to receive one half of the flat pistons, which go free of the sides of the barrel, and let them fold in, and they take hold of the links as they rise. A whole row of the pistons, which go free of the sides of the barrel by near a quarter of an inch, are always lifting when the pump is at work, and as this machine is generally worked with briskness, they bring up a full bore of water in the pump. It is wrought either by one handle or by two handles, according to the labour required. The preference, which has been given to chain-pumps over those which work by the pressure of the atmosphere, seems to have arisen from this circumstance,—that the former have been found less liable to choke.

7. *Scholia.*

1. There are many contrivances to avoid friction in pumps; but in great works, the friction of the piston is of little importance.

2. *Plungers* are pistons that nearly fill the working-barrel:

but they do not act upon the principle of the pressure of the atmosphere.

3. Valves in pumps are of various constructions: the best are the *clack*-valve, the *button* and *tail*-valve, the *conical*-valve, and the *globular*-valve.

4. It is immaterial whether a pump be placed perpendicular to the well or not, if it have a communication with it by pipes.

5. In pump-work, all contractions, or sudden enlargements in the pipes, should be avoided.

Of Jets or Fountains.

8. We have seen, that water will rise through bended pipes, to the same level as the reservoir from which it proceeds. And on the same principle, *jets*, or *fountains*, are formed.

Illus. If near the bottom of the vessel A B (see the diagram illustrative of article 4, chap. xii. p. 263.) you fasten a small pipe, *m*, bending upwards, the water will spout out through the pipe, and rise nearly as high as the surface of the water in the vessel. It will not rise quite so high, because it is somewhat impeded by the resistance of the air, and the friction against the opening of the pipe, or adjutage.

Questions for Examination.

1. How many kinds of pumps are there?
2. Describe the construction of the sucking pump.
3. Also its mode of operation.
4. Describe the construction, and explain the mode of action of the lifting pump?
5. Describe also the construction, and explain the mode of operation of the forcing pump.
6. What are the construction and principle of action of the chain pump?
7. What are *plungers* and *valves*?
8. On what principle do jets and fountains act.

Section IV.

The Fire Engine.

It is upon the principles laid down in the last section that the famous and useful invention of the fire engine is formed. It consists of two forcing pumps and a large air vessel which communicates with the pipe. In figure 1, plate i. p. 180, A B is the body of the engine, in which the water is contained; D and E are two forcing pumps, wrought by the lever F G, moved on the centre N.

The easiest mode of supplying the engine with water is that which is commonly used in London in cases of fire, when a leather pipe communicates with the orifice of one of the pipes which supplies the city with water. When this cannot be done, the water is poured by bucketts into the vessel A B, and being strained through the grating-wire N, is by the pressure of the atmosphere, raised as before described in treating of the forcing pump through the valves at the lower end of the barrels D and E, when either of the forcers ascend, and at their descent it will be forced through the other valves alternately, into the air-vessel E; the air, therefore, in this vessel being strongly compressed by its spring D, it will force the water up through the metal pipe within the vessel. The part Q, is flexible, so that its end may be directed to any part of the building where the flames predominate.

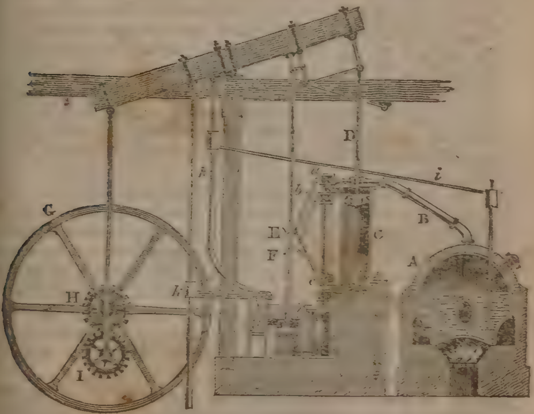
Question for Examination.

Describe and explain the construction and mode of action of the fire-engine.

SECTION V.

The Steam-Engine.

One of the noblest monuments of human ingenuity, was originally invented by the Marquis of Worcester, in the reign of Charles II. But about 1762, the late Mr. Watt began to turn his attention to this machine, and brought it to a degree of perfection, of which an idea will be conveyed by the annexed diagram, which professes to exhibit its construction and mode of operation.



Illus. A is the boiler, generally of an oblong form; and the flame, after striking on its concave bottom, circu-

lates round the sides, and sometimes returns in a pipe through the body of the water, before it is suffered to go up into the chimney. In engines there are commonly two of these boilers, so that one of them may work while the other is repairing.

B is the steam-pipe which conveys the steam to the cylinder C, which is cased, and closed at top by a plate, having a collar of leathers, through which the piston-rod D works. *a* and *c* are the steam-valves, through which the steam enters into the cylinder: it is admitted through *a*, when it is to press the piston downwards, and through *c* when it presses it upwards: *b* and *d* are the eduction-valves, through which the steam passes from the cylinder into the condenser *e*, which is a separate vessel placed in a cistern of cold water, and which has a jet of cold water, continually playing up in the inside of it. F is the air-pump which extracts the air and water from the condenser. It is worked by the great beam or lever, and the water brought by it from the condenser, after being brought into the hot-well *g*, is pumped up again by the pump *h*, and is brought back again into the boiler by the pipe *i*. *k* is another pump, also worked by the engine itself, which supplies the cistern in which the condenser is placed, with cold water.

In order to make the piston-rod move always in a perpendicular direction, a particular contrivance was invented usually called the parallel-joint. In order to make the engine itself open and shut the steam and eduction-valves, long levers are attached to them, which are moved by the piston-rod of the air-pump. This part of the apparatus is called the working-geer, and is so contrived, that the valves may be worked either by hand or by the perpendicular rod. By shutting these valves, the engine may be stopped in an instant.

2. In order to communicate a rotatory motion to any machinery by the motion of the beam of the steam-engine, there is a very large fly-wheel G on the axis of which, is a small concentric-toothed wheel. A similar toothed-wheel,

I, is fastened by straps to a rod coming from the end of the beam, so that it cannot turn round on its axis, but must rise and fall with the motion of the great beam.

A bar of iron connects the centres of these two small toothed wheels, so that they cannot quit each other. When, therefore, the beam raises the wheel I, it must move round the circumference of the wheel H, and turn it together with the fly: and it will be evident, upon consideration that the fly, driven in this manner, will make two revolutions for every one of the wheel I. This mode of moving the fly, is preferable to a crank; as it goes with twice the velocity. This contrivance is called *the sun and planet-wheel*, from the resemblance of the motion to that of those luminaries.

The valves of this steam-engine are all *puppet*-valves, as these are found least liable to be out of order, but the mode of operation in Mr. Watt's engine, will be best understood by inspecting one of them at work. however, it may not be improper here to state the actual performance of some of these engines, as they have been ascertained by experiment.

3. An engine, having a cylinder of 31 inches in diameter, and making 17 double strokes per minute, performs the work of forty horses, working night and day (for which three relays, or 120 horses must be kept), and burns 11,000 pounds weight of Staffordshire coal per day. A cylinder of 19 inches, making 25 strokes, of 4 feet each, per minute, performs the work of 12 horses working constantly, and burns 3,700 pounds of coal per day. A cylinder of 24 inches, making 22 strokes of 5 feet, burns 5,500 pounds of coals, and is equivalent to the work of 20 horses.

Questions for Examination.

1. Describe the construction of the steam-engine.
2. How is the rotatory motion communicated to this machine?
3. What is the actual performance of one of these engines?

CHAPTER XIII.

CHEMISTRY.

SECTION I.

Its Nature and Use.

Introd. Chemistry is the science which investigates the effects of the action of bodies upon each other, with the view of determining their constituent principles, and forming new compounds.

The extensive utility of chemistry is shewn by its immediate connexion with the arts subservient to the subsistence or the comforts of man. Dyeing, bleaching, tanning, glass-making, the working of metals, &c. are chemical operations. In agriculture its use is very important, because it explains the phenomena of the growth and nourishment of vegetables, and the nature and action of manures, &c. The culinary arts, the arts of baking, brewing, distilling, &c. owe their improvement to chemistry.

In medicine, it affords invaluable assistance, by giving the medical man a knowledge of the various substances used as medicines. In short, there is scarcely any art, trade, or manufacture that does not depend, either immediately or remotely, upon a knowledge of this science.

Besides, it enlarges the mind, by affording us a more extensive and intimate knowledge of nature, and procures for us some of the most sublime pleasures, and rational enjoyments.

Before we proceed to the theory, we shall describe the

principal processes employed in chemical experiments; these are—

1. Trituration.
2. Sifting.
3. Washing.
4. Filtration.
5. Decantation.
6. Lixiviation.
7. Evaporation.
8. Distillation.
9. Sublimation.
10. Crystallization.
11. Solution.
12. Precipitation.
13. Fusion.
14. Cupellation.
15. Digestion.
16. Saturation.
17. Combustion.
18. Deflagration.
19. Detonation.
20. Operations, in the dry way.
21. And in the humid way.

SECTION II.

Mechanical Operations for the Division of Bodies.

Trituration.

1. Trituration, Pulverization and Levigation, (or the reduction of solids into powders of different degrees of fineness) are necessary and preliminary operations, previous to the solids being chemically acted upon.

Brittle substances are reduced to powder by means of hammers, pestles and mortars, and stones and mullers. The annexed cut represents a pestle and mortar.

Fibrous substances, as wood, the horns of animals, elastic gum, and metals, which flatten under the hammer, cannot be reduced to powder by the foregoing methods; for these, files, rasps, knives, and graters, are used.

Sifting.

2. The separation of the finer parts of bodies from the coarser, which may want farther pulverization, is performed by sifting or washing.

A sieve consists of a cylindrical band of thin wood, or metal, having silk, leather, hair, or wire, plaited or woven

and stretched across it. Sieves are of different degrees of fineness.

Washing

3. Is employed for procuring powders of an uniform fineness, more accurately than by the sieve, but it can only be used for substances that are not acted upon by the fluid which is used in the washing.

Filtration

4. Is a finer species of sifting, through the pores of paper, flannel, fine linen, sand, pounded glass, porous stones, and the like. It is used for separating fluids from solids, or gross particles that may happen to be suspended in them, and not chemically combined with the fluids.

Thus, salt water cannot be deprived of its salt by filtration; but muddy water will deposit its mud.

Decantation

5. Separates solid particles which are diffused through liquors.

These are allowed to settle to the bottom, and the clear fluid is gently poured off. If the sediment be extremely light, and apt to mix again with the fluid, by the slightest motion, a syphon is used for drawing off the clear fluid.

Lixiviation

6. Is the separation by water or some other fluid of such substances as are soluble in that fluid, from other substances that are not soluble in it.

Illus. If a mineral consisting of salt and sand, or salt and clay, &c. be broken to powder and thrown into water, the salt will be dissolved and kept suspended, whilst the earthy matter will fall to the bottom of the vessel, and, by means of filtration, may be separated from the fluid.

Evaporation

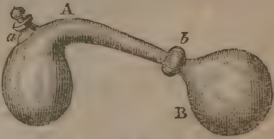
7. Separates a fluid from a solid, or a more volatile fluid from another less volatile.

Evaporation is used when the more volatile or fluid substance is not to be preserved, and various degrees of heat are employed for this purpose, according to the nature of the substances. Evaporation is performed in vessels of wood, glass, metal, porcelain, &c. of a flat shape, to expose the liquids as extensively as possible to the action of heat: evaporating vessels may be placed either over the naked fire, or in a vessel filled with sand, called a sand-bath; or they may be left in a warm room.

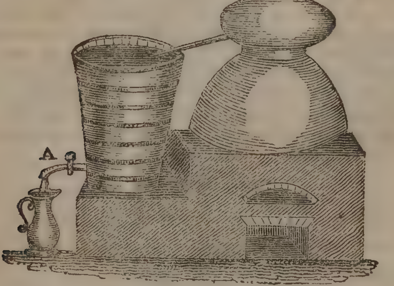
Distillation.

8. When the fluid which is evaporated must be preserved, the operation is called Distillation.

Distillation is evaporation in close vessels, to separate two fluids of different degrees of volatility, and preserve the most volatile, or both of them. The substance to be subjected to distillation is put into some vessel that will resist the action of heat, called a retort. See the annexed figure, of which A is the retort, and B a vessel for receiving the product of distillation; the latter is called the receiver. *a* is called the tubulure having a glass stopper, by which the substance, intended for distillation is poured into the retort; *b* is the neck of the receiver, into which the beak of the retort enters. Alembics and stills having beaks in the same way, are used for sublimation and distillation.



The vessel that contains the liquor to be distilled is placed upon the fire or in a sand bath, or over a lamp; the heat causes the volatile fluid to rise in the form of vapour and pass into the receiver, where it is again condensed by cold. This condensation may be assisted by making the vapour pass through a tube which is immersed in a vessel containing cold water, and called the refrigeratory. Annexed is the figure of a still in action; A is the end of the tube from whence the distilled fluid escapes.



Sublimation.

9. When the materials which are evaporated concrete in a solid form within the neck of the distilling vessels, the operation is called sublimation, and is performed in an alembic, which the annexed figure represents. A is the cucurbit or boiler;

B is the head or capital ; C is a glass tube through which the sublimed substances pass into D, the receiver.

Experiment.

C

The following beautiful experiment, illustrated by an engraving, will amply explain the operation of sublimation. Procure a bell-glass, a sprig of rosemary, a flat circular piece of iron or copper, and two drams of Benzoic acid. Heat the iron nearly to redness, sprinkle the acid on it, and invert the bell-glass with the rosemary sprig in it, over the whole. The acid will arise or be sublimed in dense fumes, and will be precipitated or settled on the cool branches of the rosemary, in the form of a beautiful *hoar frost.*

Crystallization.

10. When a salt is dissolved in water, or other fluid, and by evaporation the fluid is driven off, the salt gradually acquires a solid form, and in doing this, it arranges its particles in a particular manner ; and they are then said be be crystallized.

Some salts arrange themselves in the forms of pyramids, some of prisms of different kinds, &c. Vessels of earthenware or glass are employed for such crystallizations ; and they must be kept perfectly still, and well defended from dust or accidents.

Solution.

11. When a salt is mixed with water, it loses its state of solidity, the particles of salt are divided, and unite themselves to those of the water, forming a liquid of which all the parts are homogeneous, or of the same kind.

In this process neither the salt nor the water is decomposed, and the salt may be recovered again in its original state and quantity, by driving off the water by evaporation. The same takes place when resin is mixed with spirits of wine.

The solution of metals by acids, is, however, of a different nature; here one of the substances is altered, and different products are obtained. Vessels of glass are used for solution. The liquid used for dissolving a metal, or other solid substance is usually called a solvent.

Precipitation

12. Is the recovery or separation of a body from its solvent, by the addition of a third substance, so that the former may re-appear in a solid state.

The substance thus recovered, is called a precipitate, and the superadded body that occasions this precipitation, is called a precipitant.

Fusion.

13. The melting or causing any body to pass from the solid to the liquid state, by the action of fire, is called fusion.

The fusion of metallic substances requires vessels which will resist destruction by fire. Those vessels called crucibles are mostly, if not always, made of earthenware, or porcelain, or a mixture of clay and powder of black-lead. Some of these are barrel-shaped as A; others are indented at the side, to allow their contents to be poured out as B, and others have lids fitted to them, to prevent the sublimation or dispersion of volatile substances, such as arsenic, &c. as C.

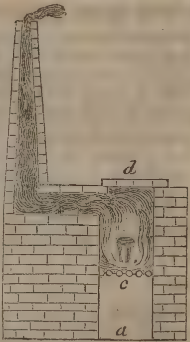
Furnaces.

For fusion, we find it necessary to employ furnaces or the blow-pipe. The various degrees of heat required for the performance of chemical operations, render a variety of fire-places or furnaces necessary for a chemist.

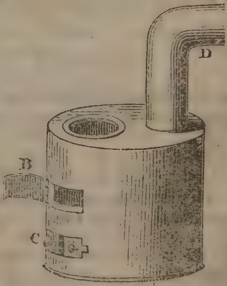
Furnaces are either open at top or covered with what is called a dome, and have a chimney or tube to carry off the heated air, smoke, &c. They are sometimes supplied with air from the natural action of the fire which rarefies the air about the ignited fuel; and which becoming specifically lighter, ascends into the chimney, whilst the colder or heavier air is forced by the atmosphere to enter at the lower part of the furnace.

Some furnaces are supplied with air by means of bellows, and those are applied to the forging of iron, or for reducing metals from their ores; this is called smelting.

Hence furnaces derive their various names, and are called *simple or open furnaces, reverberatory furnaces, the furnace for distilling by a sand heat, the cupelling or enamelling furnace, and the wind or air furnace,* which the annexed engraving represents ; *a* being the ash-pit, *c* the fire containing a crucible, *d* is a moveable cover to be taken off or put on at pleasure. There are also *blast furnaces, forges, smelting furnaces,* &c.



For common purposes, portable furnaces are used. They are extremely useful for a variety of purposes in the small way ; as in distillation, fusion, sublimation, cupellation, &c. &c. In the annexed figure of one of these furnaces, B is the fire-place, C the ash-pit, and D the chimney.



Blow-pipes.

Blow-pipes are used for diverting the flame of a candle or lamp against any bit of ore or other substance, required to be examined. They ought to have

a bulb upon the middle of their stems (according to the annexed cut,) to contain the moisture that is formed from the breath. The compound gas blow-pipe which has been a late discovery is perhaps the most generally useful instrument a chemist can possess.

Cupellation.

14. Cupellation, or the art of assaying metals and ores, is performed in a shallow crucible made of burnt bones. The impure metal or ore is put into the cupel (of which the annexed is a figure), with some oxidiseable metal, such as lead. The cupel is now put into a muffle, and the whole is submitted to the heat of a furnace. The flame passes over the cupel, oxdating the lead, which combines with the *base* part of the metal to be assayed, and leaves the pure metal (such as gold or silver) in the shape of a button at the bottom.

Digestion.

15. When a solid substance, in powder or otherwise, is left for a certain time in a fluid, and the mixture is kept exposed to a slow degree of heat, the process is called digestion.

Saturation.

16. When one substance which has an affinity to another, is mixed with as much of that other substance as its affinity will enable it to hold in com-

bination, then the former substance is said to be saturated, or the mixture to have attained the point of saturation.

If the mixture contain a greater proportion of either substance, it is said to contain an excess, or to be surcharged. The same thing must be understood of the compounds of more than two substances.

Combustion.

17. Combustion is when a body is in the act of burning in any air or gas capable of supporting flame.

Deflagration.

18. Deflagration is when the combustion is attended with explosions or cracklings.

Detonation.

19. Detonation is a pretty loud report.

Operations in the Dry and Humid way.

20. When strong degrees of heat are used, chemical operations are said to be performed in the dry way.

21. The humid way is when fluids are used in the solution of bodies.

Questions for Examination.

1. Of what importance is chemistry to mankind; and among the mechanical operations for the divisions of bodies, what are trituration, pulverization, and levigation?

2 3 4. What are sifting, washing, and filtration?

5, 6. 7 Also decantation, lixiviation, and evaporation?

8. 9. 10. Likewise distillation, sublimation, and crystallization?

11. 12. 13. Also solution, precipitation, and fusion? Here describe furnaces.

14. 15. 16. 17. Likewise digestion, cupellation, saturation, and combustion.

18. 19. 20. 21. Also deflagration, detonation, and operations in the dry and humid way.

Section II.

Elements of Bodies.

1. When we contemplate the world that we inhabit, we discover a vast variety of substances differing in their properties of weight, colour, &c. from each other. When we examine these more minutely, we discover also that almost all the bodies with which we meet, are of a mixed or compound nature. When we reduce these to the principles of which they are composed, we find that the number of simple or unmixed bodies is very limited, and that all the substances with which we are acquainted, are formed from a combination, in various proportions, of these simple bodies.

The elements of bodies, then, are those simple substances, of which in various proportions or combinations, all bodies with which we are acquainted are composed.

Obs. Formerly air, earth, fire, and water, were supposed to be the elements of which all bodies are formed. But modern improvements in chemistry have shewn that this was an erroneous supposition. For it is well known that

the air or atmosphere is a mixed body, composed of several aerial fluids or gases, so that instead of one simple kind of air, it is now known that there are several sorts of air essentially different from each other.

It is also known, that instead of one simple kind of earth, there are several kinds, quite different.

Water is found not to be a simple body, but composed of two different kinds of air united together. With the nature of fire we are very little acquainted, but this we can say; that combustible substances, either burning or otherwise, are not simple substances.

From the improvements that are continually making in the methods of analysing bodies, or separating them into their component principles or elements, many substances, once supposed to be simple, are found to be compounds; and as chemistry continues to improve, more errors of this kind may be corrected, and our inability to decompose any substance, does not prove it to be a simple body or an element, but only, perhaps, that our methods of analysis are not perfect. For the sake of covenience, however, we shall at present consider all bodies as elements or simple bodies, that have not been analysed or separated into component parts.

2. Almost every body in nature is susceptible of three several states of existence; viz. solid, liquid, and aeriform; and these states of existence depend upon the quantity of caloric combined with the body.

3. The simple substances at present known are divided into three classes; viz. imponderable bodies, as caloric, and light. Supporters of combustion, as oxygen, chlorine, iodine, and fluorine. Combustible and incombustible substances, as carbon, sulphur, phosphorus, hydrogen, nitrogen, boron, silicon, and the metals.

Questions for Examination.

1. What are the elements of bodies?
2. In how many states of existence are all the bodies in nature found?
3. What are the simple substances at present known?

SECTION III.

Caloric.

1. Heat, considered as a sensation, or in other words, sensible heat, is only the effect produced upon our organs by the motion of caloric, disengaged from surrounding bodies.

To illustrate this, let us observe, that in general we receive the impression only in consequence of motion, and it might be established as an axiom, that without motion there is no sensation. This general principle applies very accurately to the sensations of heat and cold.

When we touch a cold body, the caloric, which always exerts itself to attain an equilibrium in all bodies, passes from our hand into the body we touch, and gives us the feeling or sensation of cold.

The contrary happens when we touch a warm body; the caloric then, in passing from the body into our hand, produces the sensation of heat.

If the hand and the body it touches be of the same temperature, or very nearly so, we receive no impression of either heat or cold, because there is no motion or passage of caloric.

When the thermometer rises, it shews that the free caloric is entering into the surrounding bodies. The thermometer, which is one of these, receives it in proportion to its mass, and to the capacity which it possesses for containing caloric.

Free Caloric.

2. Free caloric is that which is not combined in any manner with any body. But as we live in a system, to the matter of which caloric has a very strong affinity, we are never able to obtain it in a state of absolute freedom.

Combined Caloric.

3. Combined caloric is that which is fixed in bodies by affinity, or elective attraction, so as to form part of the substance of the body.

Specific Caloric.

4. By the expression of specific caloric of bodies, we understand the respective quantities of caloric requisite for raising a number of bodies, of the same weight, to an equal degree of temperature.

This proportional quantity of caloric depends upon the distance between the constituent particles of bodies and their greater or less degree of cohesion; and this distance, or rather the space or void resulting from it, is called the capacity of bodies for containing caloric.

Caloric is the cause of fluidity and of vapour.

5. Bodies which transmit caloric easily, are called conductors of caloric; and according to the power of doing this, they are termed good or bad conductors. Those which do not transmit heat at all, or with great difficulty, are called non-conductors.

Obs. The best conductors of heat are metals, and the

best non-conductors are fluids, such as water and air, also charcoal.

Heat is produced in various ways; by collision, by friction, by chemical action, by the solar rays, by electricity, and galvanism.

Means of obtaining Heat.

A stream of oxygen gas upon lighted charcoal causes a most intense heat.

Heat may be produced by the mixture of some cold fluids; for example, when nitric acid is poured into a cup containing oil of turpentine, or powdered charcoal, immediate inflammation will be the consequence.

The solar rays, when collected by a mirror, or convex lens, produce the most astonishing effects in burning and vitrifying bodies.

The instruments used for measuring the quantity of heat in bodies are thermometers for fluids, and pyrometers for solids. The first of these is founded on the principle of expansion, and the second of contraction by heat.

Questions for Examination.

1. Define and illustrate what heat is.

2. Also free caloric. 3. Combined caloric. 4. Specific caloric. 5. What are conductors of caloric? 6. What are the various means of obtaining heat.

SECTION IV.

Of Light.

1. The physical properties of light are considered under optics. We now consider its chemical properties; for it seems to have considerable influence upon many chemical processes.

The effect of light upon vegetation is well

known. Many flowers follow the course of the sun; and plants that grow in houses, seem solicitous to get at the light. Plants that grow in the shade, or in darkness, are pale and without colour, and when this is the case, they are said to be blanched.

Gardeners avail themselves of this fact, to render vegetables white and tender. The more plants are exposed to the light, the more colour they acquire. A person who shall sit much in a room from which the light is greatly excluded by blinds will become pale; and we see workmen within doors appear very pale, in comparison with those who are working in the open air.

Vegetables are not only indebted to light for their colour—their taste and odour are derived from the same source.

From this cause it happens, that hot climates are the native countries of perfumes, odoriferous fruits, and aromatic resins.

Birds that inhabit tropical countries, have brighter plumage than those of the north. This is also the case with insects.

The parts of fishes exposed to light, as the back, fins, &c. are uniformly coloured; but the belly, deprived of light, is white.

2. Metallic oxides, especially those of mercury, bismuth, lead, silver, and gold, become of a deeper colour by exposure to the sun; some of them become perfectly revived, others only partially.

The yellow oxide of tungsten, if exposed to the light, loses weight, and becomes blue.

3. Light has a very great influence upon the

crystallization of salts. Many will not crystallize, except exposed to the light.

Camphor kept in glass bottles exposed to light, crystallizes in geometrical figures, on that side which is turned towards the light.

4. Many bodies, if exposed to light, either at high or low temperatures, combine with it, and emit it again, under certain circumstances. These are called *solar phosphori*. Substances of this kind have been prepared by various chemists; they have the property of shining in the dark.

Various animal and vegetable substances seem to possess a great deal of this kind of phosphorus. The glow-worm is a remarkable instance. Dead fish, rotten sea-weeds, and great numbers of insects, have this property in a great degree.

5. Instruments for measuring the degree or intensity of light are called photometers.

Effects of Light upon the Photometer.

Light of the sun at an elevation of 30° sky perfectly clear	75°
Idem, sky white	73°
Light of a blue sky at an elevation of 45°	56°
Zenith	49°
A cloudy sky	53°
A full moon	34°
Moon five days old	20°
Light from snow enlightened by the sun	57°
—— from snow in the shade	47°
—— Starry sky, March 14th, 1817	7°
—— Sky clear of stars, March 14, 1817	4° 5′
Planet Venus at an elevation of 30°, April 5, 1817	9°

Constellation of Orion, March 14, 1817 .	7°
A common candle two feet distant .	48°

Questions for Examination.

1. What are the chemical properties of light upon vegetation and animals?

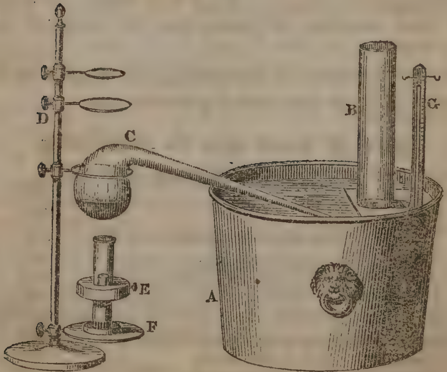
2. 3. Also upon metallic oxides and the crystallization of salts.

4. 5. What are *solar phosphori?* and what photometers.

SECTION V.

Simple Supporters of Combustion.

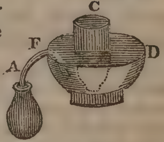
Oxygen.



For the purpose of obtaining oxygen or any other gas, the annexed apparatus will prove the most elegant and generally useful. D is a stand

with rings, supporting a retort C, and an Argand's lamp E; the latter is connected with the stand by a screw (see F.), A is a pneumatic trough, made of tin, and containing water, through which the gas proceeding from the retort, ascends into the glass jar B, placed upon a wooden shelf:—as the gas ascends into the jar, the water is displaced. G is a strong tube of glass, in which gases are detonated or inflamed by electricity.

For common purposes, and where heat is not required, a mattrass with a bent glass tube fitted to it is used (which the annexed cut represents). This may be done with a common phial and hand-basin, according to the annexed figure.—A is the mattrass; F the bent tube; C the phial; and D the basin.



1. Oxygen is a substance known only in combination with other bodies, and hath never been obtained alone. It is absorbed by combustible bodies, and converts them into acids.

Oxygen is necessary for combustion, uniting itself always to bodies which burn, augmenting their weight, and changing their properties. It is necessary for the respiration of animals. It is a constituent part of atmospheric air, of water, of acids, and of all bodies of the animal and vegeta-

ble kingdoms. Combined with light and caloric, it constitutes oxygen gas.

When a body has only a small quantity of oxygen united to it, nor sufficient to make it an acid, it is called an oxide.

Thus, most of the metals can only be reduced to the state of oxides by the addition of oxygen. This was formerly called calcination, and the metal added to oxygen was called a calx. Thus, the calx of mercury, of tin, &c. When the base has only just a sufficient quantity of oxygen to exhibit the properties of an acid, the termination *ous* is used, such as the sulphureous acid, the phosphorous acid, &c.; but when it has a greater portion of oxygen, the termination ends in *ic*, as sulphuric, phosphoric and nitric acid.

Chlorine.

2. Chlorine is assimilated to oxygen as an elementary substance. In the gaseous state it is of a yellowish green colour, and it is this property which suggested its name. Its odour is extremely disagreeable.

Chlorine is not capable of being respired, and even when mixed in very small quantities, with common air, it renders it extremely pernicious to the lungs. It has never been found pure in nature; but exists in many compounds, paticularly in table, or sea salt.

Iodine.

3. Iodine is obtained from sea weeds, such as barilla and kelp: like chlorine and oxygen, when in the state of vapour, it supports combustion. Its vapour is of a violet hue. It is obtained in brown shining scales.

Fluorine.

4. Fluorine is the supposed base of fluoric acid obtained from fluor-spar; but it has never yet been obtained in a separate state.

Questions for Examination.

1. Define and illustrate oxygen.
2, 3, 4. Also chlorine, iodine, and fluorine.

SECTION VI.

Combustible and Non-combustible Substances.

Carbon.

1. *Modern chemists consider the diamond as pure crystalline carbon.* The diamond is one of the hardest bodies known; for it resists the most highly tempered steel file, and can be ground or polished only by diamond powder. It takes an exquisite and lasting polish. It has a great refractive power; and hence its lustre, when cut into the form of a regular solid, is uncommonly great.

The diamond like other combustible bodies, burns, by a strong heat, with a sensible flame, attracting oxygen, and becoming wholly converted into carbonic acid gas during that process. It combines with iron by fusion, and like common charcoal, converts it into steel.

Common charcoal, the base of animal and vegetable matters, is widely diffused throughout nature. It is a compound of carbon with earths, alkalies, salts, &c. united to a portion of oxygen; it is properly an oxide of carbon. It is black, sonorous and brittle: and is obtained from many substances, but chiefly from wood.

When pure, it resists the greatest heat in close vessels. With nitrate of potash, it detonates in a hot crucible, leaving a fixed alkali behind. It does not mix with the metals, but restores their oxides to a metallic state.

Sulphur.

2. Sulphur or brimstone, is a simple combustible substance, which nature frequently presents in a pure state.

It is found in the earth in a loose powder, or in a solid state; and either detached or in veins. It is found also in the neighbourhood of volcanoes, and is deposited as a crust on stones contiguous to them. It is frequently met with in mineral waters, sometimes also in coal-mines, and it is found in combination with most of the metals; when united to iron, it forms *martial pyrites* or sulphuret of iron.

In order to form it into rolls, it is melted and poured into wooden moulds; it is then called roll sulphur.

Flowers of sulphur are formed by subliming purified sulphur with a gentle heat in close chambers.

Sulphur is a non-conductor of electricity, and hence it becomes electric by friction—it unites to most of the metals; rendering them brittle and fusible.

Phosphorus.

3. Phosphorus is commonly found united to oxygen, in the state of phosphoric acid, which is found plentifully in different animal, vegetable, and mineral substances.

It is a yellowish semi-transparent substance, of the consistence of wax. It is luminous in the dark, at the common temperature of the atmosphere. It takes fire spontaneously, and burns rapidly in the open air, (at 122° of Fahrenheit,) with a brilliant white flame, and is converted into phosphoric acid.

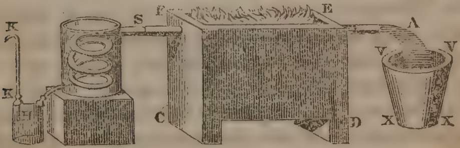
The combustibility and luminous property of phosphorus have given birth to various experiments, and the following will evince its characteristic properties in a pleasing manner.

That phosphorus burns at the usual temperature, appears by writing with it upon black or purple paper, or any other smooth surface. The writing will be luminous in the dark, as if on fire. The fiery appearance vanishes by blowing upon it, but becomes visible again after a few seconds.

The combination of any substances with sulphur, phosphorus, or charcoal *without oxygenation*, has the termination of its name in *et*; thus sulphur and iron form sulphuret of iron, phosphorus and lime form phosphuret of lime, &c.

Hydrogen.

4. As hydrogen gas is produced by a different process from other gases; we insert the annexed cut.



C D is a furnace, through which an iron tube or gun barrel, E F, passes. In this tube there is a quantity of iron filings, over which the steam of water proceeding from a retort A, placed in a large crucible V, passes, and is decomposed; the oxygen of the water, combining with the iron filings, whilst the hydrogen is set free, to pass through a vermicular tube into a gas bottle H,

and from thence by the tube K K into any convenient receiver.

Hydrogen is one of the constitutent elements of water. It is also one of the ingredients of bitumen, of oils, fat, ardent spirits, ether, and in fact of animal and vegetable bodies: it also forms a part of all animal and vegetable acids; and it is one of the bases of ammonia, and of various compound gases.

It possesses so great an affinity for caloric, that it can be obtained only in the state of gas. It is consequently impossible to procure it in the concrete or liquid state, independent of combination. Hydrogen united to caloric and light, forms hydrogen gas. Hydrogen gas united to carbon, forms carburetted hydrogen gas, by which streets, shops, theatres and churches are lighted.

Nitrogen.

5. Nitrogen, called also azote, is a simple body, very abundant in nature, though not producible in an uncombined state. It is one of the component parts of atmospheric air, and also of all animal and vegetable bodies, nitric acid, and ammonia. It enters into combination with light and caloric. This compound is called nitrogen gas.

Boron.

6. Boron is a powder of a brown colour; inodorous and insipid; electric; incombustible in covered vessels, but increases in density when the heat is augmented; insoluble in ether, oils, alchohol, and water.

Silicon.

7. Silicon is a powder of a dark colour, incombustible at a high temperature. It is so difficult to be obtained free from oxygen, that very little is known concerning it.

Questions for Examination.

1. Describe the properties of the diamond, as pure carbon.
2. 3. Also those of sulphur and phosphorus.
4. 5. Also those of hydrogen and nitrogen.
6. 7. Also those of boron and silicon.

Section VII.

The Metals.

1. The metals are among the most useful substances in nature, for most of the mechanic arts depend upon them ; and without a knowledge of them, perhaps mankind would never have attained their present degree of civilization. Their uses are still unknown to many nations inhabiting the numerous islands of the South Sea : and also to those lately discovered by Captain Ross in Baffin's Bay.

2. They are seldom found in the earth in a native or pure state, but generally in combination with oxygen, sulphur, and the acids. In their different states of combination, they are said to be mineralized, and they are then called ores.

The ores of metals are generally found in mountainous countries, chiefly in crevices of rocks, forming veins of

ore which are distinguished into *level, inclined, direct*, and *oblique*, according to the angle they make with the horizon. The part of the rock resting on the vein, is called the roof, and that on which the vein rests, the bed of the vein. The cavities made in the earth in order to extract these ores, are called mines.

The metallic matter of ores is generally incrusted, and intermingled with some earthy substance, different from the rock in which the vein is situated, which is termed its matrix. This, however, ought not to be confounded with the mineralizing substance with which the metal is combined, such as sulphur, &c

3. The art of distinguishing ores from each other, and the method of describing them with accuracy and precision, is called mineralogy.

4. The art of assaying or analysing them, in order to ascertain the component parts, forms a branch of chemistry, called the *docimastic* art.

To procure the pure metal from the ore, it is first cleared as much as possible from the foreign or stony substances with which it is blended, by first reducing the ore to powder, and then by washing. It is then *torrefied*, or wasted, to dissipate the sulphur, &c. and lastly, fused by the addition of some flux containing the coaly principle, to disengage the oxygen with which the metal has been impregnated during the previous calcination or torrefaction.

Characteristic Properties of Metals.

5. Metals appear to be simple substances. They are distinguished from all other bodies by a peculiar brilliancy, which is termed metallic lustre, and by weight, or specific gravity. They are also distinguished by their malleability, or their property of being extended under the hammer ; and

their ductility, or the property of being drawn into wire: though these two qualities are not possessed by all the metals.

All metals are fusible by a sufficient degree of heat, and when suffered to cool gradually, they crystallize into regular figures.

If a metal is continued in fusion, it loses its brilliancy, and becomes an oqaque powder, or metallic oxide or calx, acquiring weight, and absorbing a certain portion of oxygen during the transition. This process was formerly called calcination; it is now called oxidation.

The pure metal itself was formerly known by the name of regulus, as the regulus of tin, of gold, of antimony, &c.

6. That metals are calcined or oxidated in consequence of their absorbing oxygen, is proved by this process taking place only when oxygen is present, and by their giving it out in exactly the same quantity and proportion, on their reduction or return to the metallic state.

They undergo this process also from the action of humidity. The water is decomposed, its hydrogen being dissipated, whilst its oxygen unites with the metal.

Metals are soluble in acids, and are precipitated from them by alkalies. Some of the acids are decomposed during their combinations with metals, their oxygen combining with the metal, forming a metallic oxide, which is then dissolved by the remainder of the acid, forming a metallic salt. When perfectly fused, they are for the most part miscible with each other, or with other subtances, as sulphur, phosphorus, and charcoal.

If urged by a stronger heat, they are converted into a vitriform substance, or metallic glass. These metallic

glasses, as well as the oxides, possess different properties to those of the pure metals.

7. The metals are of different colours: and the metallic oxides tinge the earthy and saline glasses with which they vitrify, of various colours, conformably to the difference of their own nature.

They do this frequently, even when added but in a small quantity. Such metallic oxides as do not themselves yield a transparent glass, may deprive another of its transparency if fused with it. On the combination of other glasses with the metallic ones, and on the colouring of the first by means of the latter, depend the preparation of artificial gems and glass pastes; the pigments for enamel and porcelain painting, the enamel itself, and the glazings for earthen ware also depend upon these.

8. The operation by which metallic glasses and oxides are restored to the metallic form, is called the reduction or reviving of metals.

In the reduction of the metals from their oxides and glasses, the addition of a combustible substance is always necessary; charcoal, for instance, or such matters as contain carbon, as soap, pitch, resin, fat, and oil. In the smelting works, the fuel itself is employed as a means of reduction, by fusing the metal interspersed among the coals.

Some metals, as iron and platina grow soft before they fuse, and on this depends their very useful property of being *welded*.

Metals are the best conductors of electricity and galvanism.

Questions for Examination.

1. Of what importance are the metals?
2. How are they usually found?

3. What is mineralogy?
4. What is the art of assaying?
5. How are metals distinguished from other substances?
6. How is it proved that metals are calcined or oxidated in consequence of their absorbing oxygen?
7. 8. What is said of the colours of the metals and of their reduction?

SECTION VIII.

Mineralogy.

The metallic substances at present known are,

1. Platina	14. Zinc	27. Cerium
2. Gold	15. Bismuth	28. Potassium
3. Silver	16. Antimony	29. Sodium,
4. Mercury	17. Tellurium	30. Barium
5. Rhodium	18. Arsenic	31. Calcium
6. Palladium	19. Cobalt	32. Magnesium
7. Iridium	20. Manganese	93. Strontium
8. Osmium	21. Chrome	34. Yttrium
9. Copper	22. Molybdena	35. Aluminum
10. Iron	23. Uranium	36. Glucinum
11. Nickel	24. Tungsten	37. Zirconium
12. Tin	25. Titanium	38. Selenium and
13. Lead	26. Columbium	39. Cadmium.

The two first were formerly called noble metals, because when oxidated, they recover their metallic appearance by mere heat; but copper, iron, lead, and tin, cannot be reduced without the addition of some combustible substance, and therefore were called base metals. Zinc, and the remainder, being either not at all, or very slightly malleable, were called semi-metals.

Platina.

1. Platina is found in a metallic form in small

grains. It was unknown in Europe before the year 1748. It is brought from South America.

1. It is the heaviest, hardest, and most infusible of all the metals. It is ductile, and may be hammered into plates, or drawn into wire. It may also be welded together in a white heat.

2. In the native state, platina is sometimes mixed with iron.

Gold.

2. Gold is usually found native or in a metallic state. It is generally met with in grains, called gold-dust, mixed with the sand of rivers, being carried away by them, from the rocks and mountains, to which it had formerly adhered in leaves, or ramifications.

It is found chiefly in America, Africa and Hungary, and some has been discovered in the county of Wicklow, in Ireland, where the largest piece of native gold hitherto seen was found. Its weight was 22 ounces, and it was almost pure. Gold is of a rich yellow colour, and is the heaviest of the metals, except platina. It is not very hard when pure. It is the most ductile of all metals. The purple precipitate of Cassius, so much used in enamelling, is an oxide of gold.

Silver.

3. Silver is found native, and also combined with lead, copper, mercury, cobalt, sulphur, arsenic, &c. When found in the metallic state, it appears in grains or leaves, adhering to various substances.

It is found in the greatest quantities in Peru and Mexico; but there are silver mines in many countries.

When pure, it is of a very brilliant white colour. It is malleable, and ductile, in a great degree, though inferior to gold in these qualities.

With the nitric acid it forms a colourless solution, which stains animal and vegetable substances of an indelible black, hence it is used as a permanent ink, and is employed for dying human hair black; though for this purpose, it should be used with great caution, and much diluted, as it is extremely *caustic* or corrosive. This compound is employed for marking linen.

Mercury.

4. Mercury, or quicksilver, always appears in a liquid state, in the common temperature of the atmosphere; but in intense cold, becomes solid, resembling silver, and is then malleable.

It is found, sometimes in a pure state, but chiefly united to sulphur, when it forms cinnabar, or vermillion. It is sometimes united to silver. It is also united to the acids, and to oxygen, it is found mostly in Spain, and South America.

Rhodium.

5. Rhodium is obtained from the ore of platina. Its specific gravity exceeds 11.000. Its colour approaches to that of silver, with a tint of yellow.

It unites with sulphur, and is rendered easily fusible by it. It likewise combines with lead, copper, and bismuth; and its alloys are easily soluble in nitro-muriatic acid. Dr. Wollaston discovered rhodium and palladium.

Palladium.

6. Palladium is white, resembling platina. Its hardness is greater than that of bar-iron. Its specific gravity varies from 11.3 to 11.8.

It is malleable, but has little ductility. It fuses at a high temperature; but has not yet been found in sufficient quantities to be applied to the purposes of the arts.

Iridium.

7. Iridium is of a white colour, and brittle.

It requires for its fusion a most intense heat; its specific gravity is higher than that of platina; it is not acted upon by oxygen.

Osmium.

8. Osmium is of dark blue colour; it has not been fused, nor does it undergo any change at the most intense heat, unless in contact with air, when it becomes a volatile oxide.

Iridium and Osmium were discovered by Mr. Smithson Tennant.

Copper.

9. Copper is found native, but in small quantities. It is generally met with in the state of an oxide, or united to acids and sulphur.

There are many copper mines in Britain, Germany, &c. The largest copper-mine perhaps known, is that at the Paris Mountain, in the Isle of Anglesea.

Pure copper is of a red colour, very tenacious, ductile, and malleable. Copper may be alloyed with most of the metals. In an alloy of silver, it renders it more fusible, this

mixture is employed as a solder for silver plates. Copper when alloyed with tin, forms bronze, a metal used for making bells, cannon, statues, &c. When alloyed by cementation with the oxide of zinc, (called calimine), it forms *brass*. With arsenic, it forms white *tombac*. All the salts of which copper forms a part have a poisonous quality.

Copper is employed for making kitchen utensils, but very improperly. Kitchen utensils of tinned-iron are preferable, because iron possesses no quality injurious to health.

Iron.

10. Iron is the metal most universally diffused throughout nature. It is found in animals, in vegetables, and in almost all bodies; and it is seldom found native, but combined with a great variety of substances.

It is particularly distinguished by its magnetic properties: by its hardness and elasticity, by its ductility, and the property of being welded, but it is very difficult to fuse.

Iron soon *rusts or oxidates*, when exposed to the action of water, or a moist atmosphere.

Iron-filings agitated in water become oxidated and assume the form of a black powder called martial Ethiops.

1. *Cast Iron.*

When iron-ore is fused in large furnaces, it is made to flow into a kind of mould of sand. This first product, which is exceedingly brittle, and not at all malleable, is called cast iron, of which are formed stoves, pipes, cannon, and other articles.

Cast or crude iron contains carbon, and is therefore very brittle, and not at all malleable. Crude iron is in three states, white, grey, or black, according as it contains a larger proportion of carbon, an exact proportion of carbon and oxygen, or a larger proportion of oxygen.

2. *Wrought Iron.*

Wrought or forged iron is iron freed from all impurities by fusion. It is kept in fusion, and is all the time kneaded and stirred so as to expose every part to the atmosphere. It is then subjected to the action of hammers, or the pressure of rollers, by which means the remaining impurities are forced out. The iron is now capable of being *welded* and worked by hammers into any form.

3. *Steel.*

Iron is capable of being converted into *steel* by exposure to heat, in contact with carbonaceous substances, which unite themselves with it.

Steel is formed by imbedding in a close furnace, alternate layers of malleable iron and charcoal, and exposing them to a strong fire for six or eight days. This process is called cementation. During this operation, the iron combines with a quantity of carbon, and is converted into blistered steel. This is either rendered more perfect and malleable by subjecting it to the operation of the hammer, or it is fused, and cast into small bars, forming cast-steel.

Nickel.

11. Nickel is generally found in a metallic

state. It is of a reddish colour, not very malleable, and very difficult of fusion.

Tin.

12. Tin is scarcely ever found native. It is generally combined with sulphur, iron, and other substances.

Tin is of a colour approaching to that of silver, but somewhat duller. Next to lead, it is the softest, and the least elastic of all the metals. In tenacity, it is superior only to lead; it may be reduced to very thin leaves. It is less sonorous than copper, silver, or iron.

The oxide of tin is used for polishing mirrors, lenses, &c. and for rendering glass white and opaque, converting it into enamel.

With muriatic acid, it forms muriate of tin, of great use in dyeing. Tin combined with sulphur, forms *aurum musivum*, used by the japanners.

It alloys with other metals, forming solder. With lead and antimony, it constitutes pewter. With mercury, it is employed as tin-foil for silvering mirrors.

Lead.

13. Lead is seldom, if ever, found in the native state. It is chiefly found combined with sulphur, and is then called galena.

When exposed to heat with access of air, it fuses, and is oxidated at the surface. If this oxide be removed, more is formed, and thus the whole may be converted into grey oxide of lead.

This oxide, when exposed to a stronger heat, is converted into a yellow oxide called masticot.

If this yellow oxide be exposed to a still more violent

heat, it assumes a beautiful red colour, and becomes red lead, or minium.

Litharge is a semi-vitrified oxide of lead, obtained by keeping a stream of air upon fused lead. It is generally procured in the process of separating silver from lead.

If litharge be exposed to a strong heat, it becomes converted into glass of lead, which forms the basis of the common glazing for earthen-ware.

The acetous acid corrodes lead, and the result is a white oxide, known under the name of white lead.

All the oxides of lead are soluble in vinegar, forming acetate of lead, known under the name of sugar of lead.

Lead forms alloys with other metals which are used as solders.

Zinc.

14. Zinc is mostly procured from *calamine*, which is an oxide of zinc. When it is combined with sulphur, it is called *blende*. It is nearly the colour of tin. It is brittle.

One part of zinc alloyed with three parts of copper, forms the alloy called *brass*.

Bismuth.

15. Bismuth is often found native. It is also found in combination with oxygen, sulphur, iron, and arsenic.

Bismuth is of a yellowish white colour; it is brittle, and readily breaks under the hammer. It enters into fusion before it becomes red hot.

Bismuth alloys with all the metals. Its *amalgam* with mercury might probably be used with advantage for silvering mirrors, by adding a little of it to the amalgam of tin, used for that purpose.

Antimony.

16. Antimony is rarely found native. It is generally combined with sulphur, forming sulphuret of antimony.

Antimony is of a whitish colour; and so brittle that it readily breaks under the hammer; its interior texture appears to be laminated. Antimony combines with phosphorus and sulphur. Wine and acetous acid dissolve antimony; they then become emetic. The tartaric acid forms with it the well known salt, called tartrate of antimony and potash, or *tartar emetic*.

Tellurium.

17. Tellurium is of a colour nearly the same as that of antimony. It easily fuses, and rises in vapour at a strong red heat.

It burns, when heated in the air, with a vivid bluish green flame, sending off a dense white smoke. Its powder takes fire in chlorine.

Arsenic.

18. Arsenic is often found native. When combined with sulphur, it is called *orpiment*, or sulphuret of arsenic. It is often found united with other metals.

The colour of arsenic is grey. It is brittle and harder than copper. It soon loses its metallic lustre in the air, and becomes black.

The substance called white arsenic is an oxygenation of arsenic, so as to bring it into the state of an acid.

Arsenic is employed by dyers; and it is used as a flux in glass-houses. It is an ingredient in some glazes. It is also used in the manufacture of small shot.

Cobalt.

19. Cobalt has never been found but in a state of combination. It is found united to sulphur, arsenic, and other metallic substances.

It is of a pale or grey colour, inclining to red; it is hard, but fusible, requiring, however, almost as strong a degree of heat as is necessary to fuse iron.

Oxide of cobalt, when freed from arsenic, is known under the name of *zaffre*. Zaffre, when fused with three parts of quartz and one part of potash, forms glass of a beautiful blue colour, which, when pulverized, is the substance known by the name of *smalts*. The blue employed for colouring starch, is also made from it. It is used by the painters of earthenware, porcelain, &c. and by enamellers.

The nitro-muriatic acid dissolves cobalt, and forms a sympathetic ink.

Manganese.

20. Manganese is found only in combination. It is generally united to oxygen, for which it has a strong affinity, so that it is very difficult to preserve it in a metallic state.

The black oxide of manganese is found very generally. It is procured in the greatest purity in the neighbourhood of Exeter. It is sometimes crystallized. It is very much used for obtaining the oxygenated muriatic acid gas employed in bleaching. Also by glass makers, for destroying the green or yellow tint of glass, and for this reason has been called *glass-maker's soap*. It is likewise employed for giving a violet colour to glass and porcelain.

Chromium.

21. Chromium is a metal lately discovered.

Vauquelin gave it the name of *chrome*, because it com-

municates the red colour to the ruby, and the green to the emerald. It was found by that chemist in the state of an acid, in a substance before known, under the name of the *red lead of Siberia*.

Molybdenum.

22. Molybdenum is found united to sulphur It is in this state very like plumbago.

It is extremely difficult to obtain it in a metallic state, and is therefore very scarce, and little known. It is capable of oxygenation, so as to form an acid.

Uranium.

23. Uranium is of a grey colour, very porous and soft; more difficult of fusion than manganese. It is very little known on account of its scarcity.

Tungsten.

24. Tungsten is never found pure, and is very scarce. It is acidifiable, and its combination in that state with lime forms tungstate of lime.

It is also united to iron and manganese, in the ore called *wolfram*. The metal is brittle, hard, and very infusible. It is very little known, but is said to have one valuable property, viz. that of rendering all vegetable colours fixed. However, this does not appear to be certain.

Titanium.

25. Titanium is a newly discovered metal. It was first observed in a mineral called *menachanite*, found in Cornwall, and afterwards in an ore

called *titanite*. It is of a reddish-yellow colour, and very infusible. It is very little known.

Columbium.

26. Columbium was discovered in a mineral from Sweden, by Dr. Wollaston. It possesses a grey metallic lustre, is extremely hard, very insoluble in acids, and infusible in the fire.

Cerium.

27. Cerium was obtained from a mineral found in Sweden, very like tungsten, of a reddish colour, and which has been called *cerite*; but no researches have as yet been made on the combinations of cerium with the simple bodies.

Potassium.

28. Potassium is a bright hard crystallized body, at 32°; fuses at 136°, and its specific gravity is 0.870. It is obtained by embedding a gun-barrel in a coat of Stourbridge clay; placing in it iron filings, free from every impurity, and giving the whole a white heat; a quantity of pure potash is then to be passed through. The oxygen of the potash will attach itself to the iron filings. In this manner a greater quantity of potassium may be procured, than by galvanic decomposition. Potassium is the basis of potash in vegetables.

Sodium.

29. Sodium is a metal bearing great resemblance in its properties to potassium, but it is not so bright; its specific gravity is 0.970. It melts at 194°. It has a greater affinity for oxygen than potassium, and therefore may be obtained with the greatest facility, by putting an equal quantity of table salt and potassium in a crucible well covered, and submitting them to a good heat; the oxygen will quit the salt, and attach itself to the potassium, leaving the sodium free. It may be obtained, however, in the same manner as potassium is—by galvanism, or by passing a quantity of oxide of sodium (or soda) through iron filings in a gun-barrel. Sodium unites to the combustibles and supporters of combustion.

Barium.

30. Barium is a very heavy infusible metal, possessing the usual lustre; it is obtained in the same manner as the above, from barytes, but in so small quantities, as hardly to display its properties.

Calcium.

31. Calcium has a brilliant white lustre, which it soon loses on exposure to the air, by absorbing oxygen, being converted into the oxide of calcium; its specific gravity is supposed to be 6,000.

If heated in the open air, it burns with great splendour

as it is rapidly converted into an oxide. Calcium is obtained by the galvanic action upon oxide of calcium (pure lime); it amalgamates with mercury placed in the centre, while at the same time it gives out its oxygen to the positive wire. Calcium is the basis of the immense quantities of carbonate of lime (chalk), which are to be found in all parts of the world. It combines with the supporters of combustion, viz. in the metallic state with oxygen; and as an oxide with chlorine and iodine. It also combines with the acids forming salts.

Magnesium.

32. Magnesium is a metal possessing properties very similar to calcium, and is obtained in the same way, from pure magnesia; which, in its turn, is prepared by driving the carbonic acid by heat from the carbonate of magnesia. It exists very plentifully in sea-water, combined with other substances.

Strontium.

33. Strontium possesses metallic properties similar to the two last; like them, it rapidly absorbs oxygen from water and the air. It is obtained like the metals we have described, from an oxide, (by galvanic action), which in its turn is obtained by heat and charcoal from the carbonate, a salt found in Argyleshire and many other parts of the world. Oxide of strontium combines with chlorine, iodine, and the acids.

Yttrium.

34. Yttrium has a greyish lustre, but other-

wise has not been properly examined. It is obtained by passing potassium through its oxide while red hot. This oxide is found in a mineral which occurs in Sweden. The oxide is capable of combining with acids.

Aluminum.

35. Aluminum possesses a grey metallic lustre, which it soon loses by contact with air or water, being converted into an oxide. It is obtained by passing potassium through the oxide of aluminum when at a white heat. The oxide in its turn is obtained from sulphate of aluminum. Aluminum is the base of clays; no combinations, except with oxygen, have been made with it in the metallic state, but as an oxide it combines with acids.

Glucinum.

36. Glucinum has a grey lustre, which it loses when in contact with air or water. It is obtained by passing potassium through its oxide at a white heat. This oxide is procured from stones called emerald and beryl. The oxide combines with the acids.

Zirconium.

37. Zirconium is a metal possessing lustre like the above mentioned. It is obtained like them from its oxide, which in its turn is procured from a precious stone, found in Ceylon. The oxide combines with acids.

Selenium.

38. Selenium, which has been only very recently discovered, possesses a beautiful lustre with a slight tinge of red; but when broken, it exhibits a sort of grey brilliancy.

In many of its properties, it bears a close analogy to sulphur, but its metallic properties cannot be doubted. It is hard like other metals, but becomes soft at 212°, and fuses at a heat somewhat higher. It volatilizes about 650°, and the vapour arising from it, is yellow; when this vapour is condensed, it is like vermilion. While it cools, it is so soft as to be drawn out in threads, which are transparent, but of a ruby colour; but if they are seen by reflected light, they possess metallic lustre. Selenium combines with various substances, also with melted wax, all the combinations being of a red colour.

Cadmium.

39. This new metal, (which was discovered by M. Stromeyer in the autumn of 1817, while officially examining the apothecaries' shops in Hanover,) is described by M. Gay Lusac as resembling tin in colour, lustre (but not tarnishing in the air), softness, ductility, and the crackling sound which is heard when that metal is bent.

Cadmium, when exposed to heat, is changed into an orange-yellow oxide, not volatile, and easily reduced again to the metallic state: it gives no colour to borax; dissolves readily in acids, and forms colourless salts, from which it is precipitated white, by alkalies. By the hydro-sulphuric acid, it is precipitated yellow, like arsenic; by zinc in the metallic state. Its specific gravity at 77° of Fahr. is 8.635.

Questions for Examination.

What are the metallic substances at present known?

1. 2. 3. Define and explain the properties of platina, gold, and silver.

4. 5. 6. Also of mercury, rhodium, and palladium.

7. 8. 9. Also of iridium, osmium, and copper.

10. 11. 12. 13. Also of iron, nickel, tin, and lead.

14. 15. 16. Also of zinc, bismuth, and antimony.

17. 18. 19. Also of tellurium, arsenic, and cobalt.

20. 21. 22. Also of manganese, chromium, and molybdenum.

23. 24. 25. Also of uranium, tungsten, and titanium.

26. 27. 28. Also of columbium, cerium, and potassium.

29. 30. 31. Also of sodium, barium, and calcium.

32. 33. 34. Also of magnesium, strontium, and yttrium.

35. 36 37. Also of aluminum, glucinum, and zirconium.

38. 39. Also of selenium and cadmium.

Section IX.

Chemical Affinity or Elective Attraction.

1. The principle of all chemical operations which enables us to decompose certain bodies, and to compound others, is, that every substance has a certain peculiar affinity for other substances, but not in an equal degree.

2. Chemical affinity observes certain laws, which are called the *laws of affinity*, and which are as follow:—

1. Chemical affinity exerts its action between a number of bodies, simple or compound, and unites them chemically into one whole. Soda will combine with sulphuric acid forming a different substance from either: viz. sulphate of soda.

2. The power of chemical affinity is in an inverse ratio to that of corpuscular attraction.

3. The agency of the affinity of composition, or chemical affinity, is either assisted or retarded by different degrees of temperature.

4. Chemical affinity is accompanied by a change of temperature, as in the mixture of sulphuric acid with water.

5. The agency of chemical affinity between two or more bodies, may be dormant until it be called into action by the interposition of another, which frequently exerts no energy upon either of them in a separate state. Metals are not affected by acids until water be present.

6. The degree of energy in chemical affinity acting between various bodies, is different in different substances. Nitric acid has more affinity for potash than for iron.

7. The action of chemical affinity is either limited or unlimited; in other words, chemicals are capable of uniting in definite, or in indefinite proportions.

8. The degree of chemical affinity of different bodies, is modified in proportion to the quantities or masses of the substances employed.

Questions for Examination.

1. What is chemical affinity?
2. What laws does it observe?

Section X.

We shall now treat of the compound bodies: these are the gases, alkalies, earths, and the acids with their salts.

Gases.

Definition. By the word gas, we mean a permanently elastic, aeriform fluid or substance which has the appearance of air; gases are trans-

parent, elastic, weighty, and in most cases invisible; they cannot be condensed into a solid state by any degree of cold hitherto known.

The air or atmosphere consists of a mixture of several gases, which may be obtained separately. The gases which we shall describe are—

1. Atmospheric Air.
2. Oxygen Gas.
3. Nitrogen Gas.
4. Hydrogen Gas.
5. Carbonic Acid Gas.
6. Light Carbonated Hydrogen Gas.
7. Heavy Carbonated Hydrogen Gas.
8. Gaseous Oxide of Carbon.
9. Sulphuretted Hydrogen Gas.
10. Phosphoretted Hydrogen Gas.
11. Nitrous Gas.
12. Nitrous Oxide Gas.
13. Ammoniacal Gas.
14. Sulphurous Acid Gas.
15. Hydrochloric Gas
16. Chlorine Gas.
17. Fluoric Acid Gas.

Atmospheric Air.

1. The mechanical properties of atmospheric air, such as its weight, elasticity, &c. are considered under pneumatics. Chemistry examines all its other properties.

The air of our atmosphere consists of two elastic, aeriform bodies, called oxygen and nitrogen gases, possessing different properties; oxygen gas is capable of supporting combustion and animal life; nitrogen gas is destructive to animals, and extinguishes fire. The atmosphere contains carbonic acid; for alkalies become effervescent when exposed to it, and lime-water acquires a pellicle, or thin skin on its surface, on being exposed a sufficient time to the action of the air, even upon the highest mountains. Water also in the state of vapour is always found in the atmosphere.

Oxygen Gas.

2. Oxygen gas is an elastic invisible fluid, having neither taste nor smell, nor shewing any signs of acidity; it is 740 times lighter than the same bulk of water. Its weight is to that of atmospheric air as 1103 to 1000.

It is absorbed only by combustible bodies. It is necessary for respiration, and produces animal heat. It is considered the cause of acidity, and from this property is named oxygen, derived from two Greek words, denoting the cause of the acidity: these are οξυς, acid, and γινομαι, to produce or generate.

Oxygen gas is procured in great purity from pure oxygenated muriate of potash. We have before described the method of obtaining this and other gases.

It may likewise be obtained from the green leaves of plants, but not in sufficient quantity for chemical experiments.

Nitrogen Gas.

3. Nitrogen or azotic gas will not support life by respiration, but quickly kills animals that breathe it; plants, however, thrive, and even flourish in it.

It has no taste. It neither reddens blue vegetable colours, nor precipitates lime-water. No combustible substance burns in nitrogen gas. It cannot be absorbed by water. It unites to hydrogen, under certain circumstances, and with it constitutes ammonia. When united to oxygen in different proportions, it forms atmospheric air, gaseous oxide of azote or nitrogen, nitrous gas, nitrous acid, and nitric acid. It is a component part of all animal substances; from which it may be obtained.

Hydrogen Gas.

4. Hydrogen gas, or inflammable air, is found in a natural state in muddy waters and in marshes, in mines, in coal-pits, and in the bowels of animals. In these states, however, it is generally combined with carbon, sulphur, and phosphorus. It is exhaled from all places where there are animal or vegetable matters in a state of putrefaction.

Hydrogen gas is obtained in a state of purity by decomposing water, because its base is one of the constituent parts of that fluid. (See Section VI., Art. 4, where the mode of obtaining this gas is described, and illustrated by a cut). This gas, therefore, has been called hydrogen, from two Greek words υδορ water, and γινομαι, to generate, that is the generator of water.

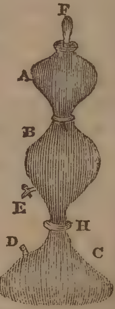
Carbonic Acid Gas.

5. Carbonic acid gas (the first elastic aeriform fluid, different from common air, that was known,) cannot support flame, nor animal life; its taste is acid, and its specific weight is to that of atmospheric air, as 1.500 is to 1000. It may be poured from one vessel into another.

This may be shewn by placing a lighted taper at the bottom of a vessel, and pouring carbonic acid gas over it from another vessel. The light will be immediately extinguished. Hence we infer that the gravity of the gas has enabled it to descend, and to displace the common air at the bottom; which being lighter, is of course obliged to ascend. Carbonic acid gas is diffused in the greatest abundance throughout nature

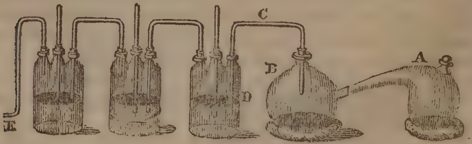
Marble, lime-stone, and chalk, consist of this acid and lime.

Carbonated water, or as it has been called, soda water, is merely water impregnated by carbonic acid. This agreeable draught is made in a series of vessels containing water and common chalk. Sulphuric acid is poured in, which unites with the lime, and at the same time the carbonic acid is expelled. This acid is absorbed by the water which is ready to receive it. The sparkling of carbonated waters is owing to the rapid escape of the gas.



What is called *soda water*, or more properly speaking, carbonated water, is made in an apparatus of which the annexed is a figure. C is a flat vessel, having a cock D, through which chalk and sulphuric acid are supplied for forming the gas, which passes through the tube H, by a valve into the vessel B, containing the water to be saturated, and which may be drawn off by the cock E. Into this vessel is inserted a tube proceeding from another vessel A, also charged with water, and having an opening F, in which is placed a stopper, and through which fresh water is occasionally poured. The water in the upper vessel, and the weight of the stopper, press and agitate that in the vessel B, by which it is more speedily impregnated. The whole is made of glass, and is termed Nooth's apparatus.

For the general purposes of impregnating water with gases, a set of glass vessels, (called Woolfe's apparatus) is used. Annexed is an engraving of this apparatus.



A is a retort having a tubulure, through which the materials for procuring any gas are passed. B is a globe or receiver, into which is inserted a tube C, bent at right angles, and communicating with the second receiver, D. From this one, another tube proceeds in the same way to the third receiver, and from the third another passes to the fourth. E is the last tube, which passes through water into any vessel, for the reception of the most volatile product, or that which will not combine with the water or other fluid contained in the three necked bottles. It will be seen that a perpendicular tube enters the middle neck of each receiver. These are *safety tubes* to prevent the apparatus from bursting, as the gas might be evolved too quickly from the retort to be absorbed by the water. Sometimes these tubes are bent at right angles, and have a drop of mercury in them, which moving up and down, according as the gas is abundantly generated, acts as a valve permitting the superabundant gas to escape. By means of this apparatus, water may be impregnâted by muriatic Acid, and nitrous gases, so as to form muriatic and nitric acids.

Exp. To shew that carbonic acid gas is fatal to animal life, put a mouse, or other small animal into a vessel filled with it, and cover the vessel to prevent the admission of atmospheric air. The animal will die in a minute or two. It is this gas which has produced so many fatal accidents at the opening of cellars or vaults, in which wine, cyder, or beer has been fermenting.

Light Carbonated Hydrogen Gas.

6. Light carbonated hydrogen gas is hydrogen gas holding charcoal in solution. There are several kinds of it obtained by different processes, which differ in their properties and in the proportions of their constituent principles.

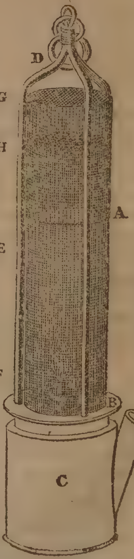
This gas is obtained from animal, vegetable, and mineral substances.

Nature produces it in marshes and ditches, on the surface of putrid water, in coal-mines, burying-places, common-sewers, and in those situations where putrid animal and vegetable matters are accumulated. It is also generated in the intestinal canal of living animals, and may be plentifully obtained from most stagnant waters. It may also be obtained during the distillation of animal and vegetable matters.

The Safety Lamp.

This gas is known in coal-mines by the name of fire-damp. Its destructive effects had probably been felt in all collieries until this moment, but for that useful invention of the immortal Davy—the safety lamp; or, as the miners in gratitude term it, "the Davy." This lamp is on the principle of the impossibility of the passage of inflamed gas through apertures of small diameters. Accordingly, wire-gauze is used for this purpose, as you see in the annexed figure of this lamp.

F is the lamp, seen in the cut, throwing up a brilliant flame. C is the reservoir, supplied with oil by the tube, I. E is a frame of thick wire to protect the wire-gauze A, which has a double top G, H. The frame has a ring D attached to it for the convenience of carrying it. The wire-gauze is well fastened to the rim B.



Heavy Carbonated Hydrogen Gas.

7. This gas was first noticed by some Dutch chemists, who observed in it a particular property, that when it was combined with oxygenated muriatic acid gas, the aeriform state of both fluids was destroyed, and oil was produced; for which reason they called it olefiant gas.

This gas is obtained in decomposing spirit of wine, by sulphuric acid in a great heat. It is also obtained abundantly, when alcohol is passed through a red-hot earthen tube. Sulphuric ether, mixed with sulphuric acid, and subjected to heat, also affords it.

Gaseous Oxide of Carbon.

8. Gaseous oxide of carbon was first described by Dr. Priestley, but with its true nature we have been but lately acquainted. It is exceedingly noxious; animals die in it instantly. It is obtained from chalk and filings of zinc.

Sulphuretted Hydrogen Gas.

9. Sulphuretted hydrogen gas has the properties of an acid; for when absorbed by water, its solution reddens vegetable blues.

It combines also with alkalis, earths, and with several metallic oxides This gas has an odour resembling that of putrid eggs. It kills animals, and extinguishes burning bodies. It is inflammable when mixed with oxygen gas, or atmospheric air.

It is this gas which gives their peculiar smell to the waters of Harrowgate, Aix-la-Chapelle, and St. Bernard's Well at Edinburgh.

Phosphoretted Hydrogen Gas.

10. Phosphoretted hydrogen gas consists of phosphorus dissolved in hydrogen gas.

It is the most combustible substance in nature, and is distinguished from all other gases by taking fire when brought in contact with atmospheric air. When mixed with oxygen gas, or with oxygenated muriatic acid gas, it burns violently. When bubbles of it are suffered to pass through water, they take fire in succession as they reach the surface of the fluid. Its smell resembles that of putrid fish.

Phosphoretted hydrogen gas is also found naturally. The air which burns at the surface of certain springs, forming what are called burning springs, and the ignis fatuis (jack o'lantern,) which glides along burying grounds, consists of this gas.

Nitrous Gas.

11. Nitrous gas, is an aeriform fluid, consisting of a certain quantity of nitrogen gas and oxygen.

It is colourless, having no sensible taste, and is neither acid nor alkaline; it cannot be respired. The greater number of combustible bodies cannot burn in it. It is, nevertheless capable of supporting the combustion of some bodies. Phosphorus burns in it when introduced in a state of inflammation, Homberg's pyrophorus takes fire in it spontaneously.

It is obtained from copper and nitric acid diluted with water.

Nitrous Oxide Gas.

12. Gaseous oxide of azote, or nitrous oxide, is a permanent gas, in which animals, when con-

fined, give no signs of uneasiness at first, but soon become restless, and then die.

When mingled with atmospheric air, and then received into the lungs, it generates highly pleasurable sensations. It excites the body to action, and rouses the faculties of the mind, inducing a state of great exhilaration, and an irresistible propensity to laughter, a rapid flow of vivid ideas, and unusual vigour and fitness for muscular exertions; in some respects resembling the sensations attendant on intoxication without any langour, depression of spirits, or disagreeable feelings afterwards, but more generally followed by vigour, and a disposition to exertion, which gradually subsides.

Ammoniacal Gas.

13. Ammonical gas is composed of hydrogen and nitrogen, rendered gaseous by the addition of caloric.

This gas suffocates animals, and extinguishes burning bodies, like all the other suffocating gases; but it is slightly inflammable, increasing the flame of a taper before it extinguishes it.

Sulphurous Acid Gas.

14. Sulphurous acid gas is no where found in a natural state, but is entirely a production of art.

It is obtained by exposing to heat in a retort, sulphuric acid, while it is exercising an action on some combustible body, as oil, charcoal, mercury, &c.

Sulphurous acid gas is twice as heavy as atmospheric air. It extinguishes burning bodies, and suffocates animals. It first reddens, and then destroys most of the vegetable colours. It has the property of whitening silk, and giving it a lustre.

Hydrochloric Gas.

15. Hydrochloric or muriatic acid gas, is obtained by exposing to heat, fuming muriatic or hydrochloric acid, put into a retort, the beak of which is introduced below a bell glass filled with mercury, and placed on the shelf of a mercurial pneumatic apparatus.

It is heavier than atmospheric air, suffocates animals and extinguishes a lighted taper; but first enlarges its flame, and makes it appear of a green or blueish colour at the edges.

Chlorine Gas.

16. Chlorine or oxygenated muriatic acid gas, is the muriatic gas deprived of its hydrogen.

This gas is not invisible, like the other gases; but is of a greeish yellow colour.

This gas destroys vegetable colours only, rendering all flowers, and the green leaves of plants, white; and alkali is not capable of restoring their colours.

Hence this acid is now very generally employed in the gaseous or the liquid state, to whiten thread, cotton inen, wax, &c.

Fluoric Acid Gas.

17. Fluoric acid gas may be obtained by decomposing fluate of lime (Derbyshire spar) by means of sulphuric acid.

The most remarkable property of this gas is its power of dissolving silex; it therefore dissolves glass, crystal and various precious stones. It is heavier than common air. It does not maintain combustion, nor can animals breathe it.

It has no action upon platina, gold, silver, murcury, tin, lead, antimony, cobalt, nickel, or bismuth, but corrodes iron, arsenic, and manganese. Its property of dissolving silex, makes it useful in etching on glass, which is done either by means of the gas itself, or the liquid acid.

There are a variety of other gases, the enumeration of which in this place would be attended with little utility to the juvenile reader.

Questions for Examination.

1. Define what a *gas* is, enumerate the principal gases already known; and describe atmospheric air.
2. 3. Describe oxygen and nitrogen gas.
4. 5 Also hydrogen and carbonic acid gas.
6. 7. Also light and heavy carbonated hydrogen gas.
8. Also gaseous oxide of carbon.
9. Also sulphuretted hydrogen gas.
10. Also phosphoretted hydrogen gas.
11. 12. Also nitrous gas and nitrous oxide gas.
13. 14. Also ammoniacal gas and sulphurous acid gas.
15. What is hydrochloric gas?
16. 17. What is chlorine gas, and what fluoric acid gas?

SECTION XI.

Alkalis.

Alkalis are incombustible, soluble in water, and possess an acrid urinous taste. When mixed with silicious substances, and exposed to great heat they form glass.

The general characteristic properties of alkalis are,

1. On urinous caustic taste.

2. Solubility in water, even when previously combined with carbonic acid.

3. The extreme readiness in combining with the acids; and even in precipitating from them the metals with which they had previously been combined.

4. The power of changing vegetable blues to a green colour.

5. Their power in rendering oils miscible with water, and so forming soap.

6. Their peculiar crystallization, or definite form.

7. Their volatility; that of ammonia at a low temperature, and of soda and potash at high ones.

They unite with acids and form new compounds, in which both the acid and alkaline properties are more or less lost. They render oils miscible with water; they change blue vegetable colours to green, red to violet, and yellow to brown. Blue colours that have been turned red by acids, are again restored by alkalis to their primitive colours. They attract water and carbonic acid from the air; they unite to sulphur; they exert a great solvent power on animal fibre. This property is called causticity; they also corrode wollen cloth, and if sufficiently concentrated, convert it into a jelly. The alkalis may thus be enumerated: potash, soda, ammonia, barytes, strontia, lime and lithium.

Potash.

1. Potash is a vegetable alkali, but it is doubtful whether it exists completely formed in the vegetable, or whether it is produced during the operation of combustion.

Potash readily combines with fat substances, and renders them soluble in water; these combinations form soap. Wine lees may be rendered almost entirely into alkali by combustion. This alkali is greenish, and is considered pure. The combustion of wine-stone also furnishes very pure alkali, but neutralized; it is known under the name of carbonate of potash, or salt of tartar.

If potash and silex are fused together, the combination forms glass, but this product differs in its properties according to the respective quantities of silex and potash, of which it is composed.

Soda.

2. Soda, or the mineral alkali, greatly resembles potash. It is obtained from the ashes of marine plants; as sea-weed, &c

The combination of soda, or potash, with oils, or fat, forms soap; the union with potash affords soft soap, and the combination of soda with the same substances makes hard soap.

Mottled soap is made by disposing the ley through the soap, or by adding to it a quantity of solution of sulphate of iron, which, by its decomposition, deposits its oxide through the soap, and gives it a variegated appearance. In some manufactories, the black oxide of manganese is made use of for the same purpose.

Yellow soap is made of tallow and resin with an alkali.

Ammonia.

3. Ammonia, or the volatile alkali; is distinguished from the former alkalis by a very sharp pungent smell, and by its great volatility.

We are not able to produce it in the solid form, but it always appears either combined, or in the state of a liquid (liquid ammonia,) or in the aerial form; and then it is

called ammoniacal gas. Its compounds are solid only when it is combined with acids.

Barytes.

4. Barytes has never yet been found free from all combination.

It may be obtained in a state of purity by the calcination of its carbonate or nitrate, which is the heaviest mineral known. For this reason carbonate of barytes has been termed ponderous spar. To animals it is a deadly poison.

Strontia.

5. Strontia is found in the state of a carbonate; that is to say, combined with carbonic acid, in a vein of lead ore, at Strontia, in Argyleshire, in the western part of Scotland.

Strontia is either of a bright green colour, or transparent and colourless.

Lime.

6. Lime, called also the calcareous earth, is now generally considered as an alkali, as it possesses the properties of that class of substances in a striking manner, its sparing solubility in water excepted.

It is found very abundantly, though never pure or in an uncombined state. It is always united to an acid, and very frequently to the carbonic acid, as in chalk, common lime-stone, marble, calcareous spar, &c. It is contained in the waters of the sea, is found in vegetables, and is the base of the bones and shells of animals.

Its combination with sulphuric acid forms sulphate of

lime, gypsum, or plaster of Paris. With fluoric acid it constitutes fluate of lime, or Derbyshire spar.

Lithia.

7. For the discovery of the new fixed alkali lithia, having for its base a new metal (lithium), we are indebted to a pupil of Berzelius, M. Arfvresdon, who obtained it from petalite, a mineral which by his analysis was found to be composed of silica 80 parts, alumina 17, and the new alkali 3 parts.—It is extracted from the petalite by calcining the latter, in powder, with carbonate of barytes, separating the earths, and obtaining the alkali combined with an acid.

Its combinations with acids are, generally, very fusible. The sulphate and muriate liquefy below a red heat; the carbonate when red-hot, acting violently on the platinum crucible. The former crystallizes readily, and retains no water of crystallization; nor is their solution precipitable by muriate of platinum, or by tartaric acid. The nitrate crystallizes in rhomboids, and attracts moisture: the muriate is highly deliquescent; the carbonate is with difficulty soluble in water; and when evaporated the salt crystallizes in slender prisms, it has a greater capacity for saturating the acids than even magnesia.

Alkalis are substances which have a great affinity for the acids; and the substances formed by the union of an acid and an alkali are called neutral salts which have neither acid nor alkaline properties.

Questions for Examination.

1. What are alkalis? how many of them are there? and what is potash?

2. 3. 4. Describe Soda; Ammonia, and Barytes.
5. 6. 7. Also Strontia, Lime, and Lithia.

Section XII.

Of the Earths.

All the earth and stones which we tread under our feet, are composed of a few elementary earths, viz. silex, alumine, magnesia, glucine, yttria and zircon.

Silex.

1. Silex, or silicious earth, is the principal constituent part of many compound earths and stones.

It is the base of almost all the scintillating stones, such as flint, rock-crystal, quartz, agate, calcedony, jasper, &c. The sand of rivers and of the sea shore, chiefly consists of it.

Silex, when perfectly pure, is a white powder; it is insipid, without smell; rough to the touch, and scratches metals and glass.

It is not acted on by any of the acids, except the fluoric. In a state of extreme division, it is soluble in alkalis; when melted with them, it forms glass. Silex exists almost in a state of purity in rock-crystal.

Alumine.

2. Alumine derives its name from alum, of which it is the base.

Pure alumine is white, soft to the touch, insipid, adheres to the tongue, and occasions a dryness in the mouth. When moistened with a small quantity of water, it forms a tenacious ductile paste. When heated to redness, it

shrinks in bulk, and at last becomes so hard, as to strike fire with flint. After being ignited, it is no longer capable of being kneaded with water. It recovers this property by solution and precipitation.

It slowly dissolves in all the acids; and possesses a powerful attraction for lime. The most intense heat of our furnaces is not able to melt it alone, but it becomes fusible when lime is added. By a mixture with water and silex it acquires great solidity, and is employed in many of the arts.

Magnesia.

3. Magnesia is sometimes found pure in nature; but it is generally obtained by art from some of its combinations.

It gives a peculiar character to the substances of which it forms a part. The stones which contain magnesia in a considerable quantity, have generally a smooth and unctuous feel, a greenish colour, a fibrous or striated texture, and a silky lustre. Among them we may mention talc, amianthus, steatite, serpentine, chlorite, asbestos, &c.

The method of procuring magnesia pure, is to precipitate it by means of an alkali, from sulphate of magnesia.

Glucine.

4. Glucine a primitive simple earth, lately discovered by Vauquelin, in the beryl; is a white granulated earth which effervesces with acids; but it has not yet been found in sufficient quantities to be applied to any use.

Zircon.

5. Zircon is a simple and primitive earth, discovered in the island of Ceylon.

It has a white colour, is rough to the touch; like silex, has no taste, and is not soluble in water. Its specific gravity is at least 4,300, that of distilled water being 1,000. It is little known, and not applied to any use.

Yttria.

6. Yttria is the heaviest of the earths. Its specific gravity is 4.842, and it resembles glucine in several of its properties.

Questions for Examination.

1. Of the earths already known describe silex.
2. 3. Describe also alumina, and magnesia.
4. 5. 6. Also glucine, zircon and yttria.

SECTION XIII.

Acids and their Salts.

Acids are either solid, liquid, or gaseous. They have so strong an attraction for water, as to be generally incapable of appearing in a solid form.

General characteristic properties of Acids.

1. They are sour when applied to the tongue.
2. They change vegetable blues to a red colour.
3. They combine with metals and metallic oxides: among the latter are included earths, and alkalis: with all these they form salts.
4. They combine with water in all proportions. In this state, they are said to be diluted. Very

many contain oxygen as one of their components: but this substance is by no means a necessary ingredient in acids; for there are several which possess the above properties, which do not contain oxygen.

All the acids combine with the alkalis. These combinations have been termed neutral salts. Example—Sulphate of soda, which is produced by a combination of sulphuric acid with soda. These salts are easily formed by art: and Nature exhibits a great number, especially of those which are formed by acids of simple radicals; example—Sulphate of lime.

Neutral salts are distinguished by two names; one expressing the acid, and the other the alkaline base; example—Sulphate of lime is composed of sulphuric acid and lime.

All metallic substances combine with at least some of the acids; example—Sulphate of iron is formed by the union of iron with sulphuric acid.

When a metallic substance is put into an acid, the first requisite, in order that it may dissolve, is, that it become oxidated in it, the acid first giving up a part of its oxygen to the metal; or rather, by decomposing water which may be present; the oxygen combining with the metal, whilst the hydrogen is set free.

In metallic solutions, an effervescence, or disengagement of gas, often takes place. The gas disengaged by nitric acid, is nitric gas; that disengaged by sulphuric acid, is sulphurous acid gas, provided this acid has furnished the oxygen; but it is hydrogen gas, if the oxygen has been furnished by the water.

In general, the metals do not take from these acids all their oxygen; they do not reduce the one to azote, and the other to sulphur; but to nitrous gas and sulphurous acid, which cannot exist but in a gaseous state.

Metallic substances dissolve without effervescence, when they have been previously oxidated; example, White oxide of lead will dissolve in acetic acid when metallic lead will not.

A metal does not dissolve with effervescence in oxygenated muriatic acid, or chlorine.

Silver, mercury, and lead, are not soluble in muriatic acid, when exposed to it in their metallic state; but if previously oxidated, they are exceedingly soluble, and the solution takes place without effervescence.

Table of the chief acids, whose general properties deserve to be known.

I. Mineral Acids.

1. Sulphurous.
2. Sulphuric.
3. Nitrous.
4. Nitric.
5. Muriatic or Hydrochloric.
6. Chloric.
7. Carbonic.
8. Fluoric.
9. Boracic.

II. Metallic Acids.

10. Arsenious.
11. Arsenic.
12. Tungstic.
13. Molybdic.
14. Chromic.
15. Columbic.

III. Vegetable Acids.

16. Acetic, or Acetous.
17. Malic.
18. Oxalic.
19. Citric.
20. Tartaric.
21. Benzoic.
22. Camphoric.
23. Gallic.
24. Succinic.
25. Suberic.

IV. Animal Acids.

26. Phosphorous.
27. Phosphoric.
28. Bombic.
29. Sebacic.
30. Laccic.
31. Lactic.
32. Saccho-lactic.
33. Uric.
34. Prussic.
35. Pyrolygneous.

Note. The salts produced by the union of any acids,

which end in *ous*, have their terminations in *ite*. Thus sulphur*ous* acid and potash form sulph*ite* of potash. Neutral salts formed by acids ending in *ic*, have their terminations in *ate*, thus, sulphu*ric* acid and potash form sulph*ate* of potash.

Sulphurous Acid.

1. Sulphurous acid, is sulphur combined with oxygen, but not to saturation. It is the sulphurous acid gas (described in sect. 10. Art. 14.) when absorbed by water.

The salts formed by the combination of this acid with different bases, are called sulph*ites*; they are not employed for any useful purpose.

Sulphuric Acid.

2. Sulphuric acid, formerly called oil of vitriol, is formed by the combination of sulphur, which is its base, and oxygen.

Sulph*ates* are neutral salts, formed by the sulphuric acid with certain bases.

Sulphate of potash, formerly called vitriolated tartar, is produced by the combination of the sulphuric acid and potash. It is found frequently in mineral waters.

Sulphate of soda, formerly called Glauber's salt, is formed by the combination of soda with the sulphuric acid.

The sulphates of iron and copper are used in dyeing, &c.

Sulphate of lime, or plaster of Paris, is used for making casts, busts, &c.

Nitrous Acid.

3. Nitrous acid, exists in the state of gas, in the form of a red vapour; it is nitrous gas combined with a quantity of oxygen.

Nitrous acid is procured from sulphate of iron, deprived of its water of crystallization by heat, and an equal weight of dry nitrate of potash. It may also be obtained by decomposing nitrate of potash, by means of sulphuric acid with the assistance of heat.

The salts formed with this acid are very little known.

Nitric Acid.

4. The constituent principles of this acid, are oxygen and nitrogen. It differs from the last mentioned acid, only in not having any nitrous gas in a loosely combined state. Oxygen and nitrogen with caloric, form nitrous gas. This gas with a greater quantity of oxygen, forms nitric acid.

Nitric acid is transparent, liquid, and colourless; sold in the shops by the name of aqua-fortis. It is procured by re-distilling nitrous acid, or at least heating it till it is deprived of its fumes.

The combinations of nitric acid with different bases, are called *nitrates*. Nitrate of silver is the lunar caustic used by surgeons. It is also used in making indelible ink for marking linen.

These salts have the property of detonating with, or inflaming charcoal, and other easily imflammable bodies, at a red heat. It is upon this property, that the composition of gunpowder is founded, which consists of five parts of nitrate of potash, or salt-petre, one of charcoal, and one of sulphur.

Muriatic, or Hydrochloric Acid.

5. Muriatic or hydrochloric acid, formerly termed marine acid, or spirit of salt is composed

of hydrogen and chlorine. Its combinations with earths, alkalis, and metals, form hydrochlorates or Muriates.

Muriate of potash, formed by the combination of muriatic acid with potash, is found in sea-water and old plaster. It has a strong, bitter disagreeble taste.

Muriate of Soda, (marine, common or rock salt,) formed by the combination of muriatic acid with soda, is found native in mines, in many places, but particularly in Poland and Hungary. It is also obtained from sea-water by evaporation, &c.

Muriate of ammonia, or sal-ammoniac formed by the combination of muriatic acid with ammonia, is found native in mines, in many parts, particularly in the neighbourhood of volcanoes.

Muriate of lime is found in mineral waters of the sea, to which it contributes to give their bitter taste.

Muriate of barytes is not known to exist native.

Muriate of lead is the pigment known by the name *patent yellow.*

Chloric Acid.

6. Chloric acid, formerly called oxygenated muriatic acid, is muriatic acid deprived of its hydrogen.

It removes the stain of common ink, though it does not affect printer's ink. It is therefore used for cleaning books and prints. Half an ounce of minium or red oxide of lead, being added to three ounces of muriatic acid, will render it fit for this purpose.

Nitro-muriatic acid, called formerly aqua-regia, is an acid analogous to chloric acid. This acid has the property of dissolving gold and platina, which cannot be acted upon by any other acid.

Chlorate of potash, or oxygenated muriate of potash is made by introducing the chlorine gas into a solu-

tion of potash. This salt has the property of detonating with sulphur, charcoal, &c. and has been used for making gunpowder; but the manufacture and use of this powder are very dangerous.

Carbonic Acid.

7. Carbonic Acid, exists in the gaseous state, and in combination with different bases constitutes the salts termed carbonates.

Carbonate of potash, is made by exposing a solution of potash to the carbonic acid gas until saturated.

Carbonate of soda is decomposed by quick lime, by the acids, and by fire, so also, is the former carbonate.

Carbonate of ammonia, or concrete volatile alkali, may be obtained from many animal substances, but it is not found native. It is a combination of carbonic acid with ammonia.

Carbonate of barytes has no taste, is not altered in the air, is almost insoluble in water, but is decomposed by heat and by all the acids.

Carbonate of magnesia, or common magnesia is obtained by precipitation with the carbonate of soda, from the sulphate of magnesia. It loses its water and acid by calcination, the residue being pure magnesia, sometimes called calcined magnesia.

Fluoric Acid.

8. Fluoric acid, is composed of fluorine and oxygen. In a gaseous state it forms fluoric acid gas; united to water, it constitutes liquid fluoric acid.

It exists completely formed in fluate of lime, known under the name of fluor or Derbyshire spar.

The distinguishing property of the fluoric acid is, its power of dissolving silex, and being employed for etching on glass.

Boracic Acid.

9. Boracic acid is a concrete acid extracted from borax, a salt brought from India. Its base is unknown.

Boracic acid exists in brilliant, white scales, soft, and unctuous to the touch. Its taste is bitterish, with a slight acidity.

Borate of soda, or borax, formed by the combination of the boracic acid with soda, is found in a crystallized state at the bottom of certain salt lakes, in a barren volcanic district of the kingdom of Thibet. A still purer kind comes from China. When reduced into a white opaque light it is called calcined borax.

Arsenious Acid.

10. Arsenious acid, is metallic arsenic, oxygenated in the first degree, and therefore called arsenious acid.

The white arsenic of the chemists' shops is chiefly obtained from the arsenical ores of cobalt.

Arsenic Acid.

11. Arsenic acid produced only by art, appears in the form of a white powder.

Remark. All the preparations of arsenic are deadly poisons; the hydro-sulphurets are the best antidotes. A weak solution of hydro-sulphuret of potash, soda, or lime, is therefore often administered with success, if given in time, to persons who have been posioned by arsenic. Sulphurous, mineral, or the Harrowgate water may also be given. In such cases, oil, milk, butter, &c. which are too often resorted to, should never be employed, if a sulphuret, or hydro-sulphuret, can possibly be procured.

Tungstic Acid.

12. Tungstic acid is procured from a mineral called tungsten, which is a combination of this acid with lime (tungstate of lime), or from wolfram, which is this acid united to iron and manganese.

Molybdic Acid.

13. Molybdic acid is molybdena oxygenated; for this metal is susceptible of oxygenation to such a degree as to become a concrete acid.

Chromic Acid.

14. Chromic acid is found combined with oxide of lead, in the mineral called chromate of lead, or the red lead of Siberia; also united to iron, alumine, and silex, in the substance called chromate of iron.

This acid has the peculiar property of forming the most brilliant colours with whatever metal it combines: chromate of lead is an intense yellow, chromate of mercury, a brilliant red, and chromate of silver, a beautiful violet.

Columbic Acid.

15. Columbic acid is found in the lately discovered ore called columbium, or columbate of iron.

Acetic Acid.

16. Acetic or acetous acid exists, mixed with other substances, in common vinegar. Since this acid is very volatile, it is obtained pure by distil-

ling vinegar in a sand-heat. In this state, it is called distilled vinegar.

Its base is carbon, hydrogen and oxygen. The same substances form the bases of the other vegetable acids, but in different proportions.

The acetites of potash and soda, are obtained by neutralizing the carbonates of these alkalis with acetous acid, and evaporating and crystallizing the solution.

Acetate of lead or sugar of lead, is composed of lead and acetic acid: hence acetic acid for preparing aromatic vinegar is usually obtained by pouring sulphuric acid on the sugar of lead in a retort and distilling the acetic acid in a receiver prepared for the purpose. Here we have an example of decomposition; for the sulphuric acid must combine with the lead before the acetic acid will come over. This distillation must be carried on in a sand-bath. Aromatic vinegar is merely acetic acid with a little camphor and oil of bergamot dissolved in it.

Malic Acid.

17. Malic acid is found in the juice of unripe apples and some other fruits.

Oxalic Acid.

18. Oxalic acid is prepared from sugar by mixing it with nitric acid. It is highly poisonous, and many deaths have occurred by mistaking it for Epsom salts, which are very like it.

Citric Acid.

19. Citric acid is found in the juice of lemons

and oranges, unripe grapes, and other sour fruits. It is also called concrete lemon juice, and is used for a variety of purposes. It is a very useful substance for taking stains of ink out of linen.

Tartaric Acid.

20. The tartar found adhering to wine casks, is a salt composed of a peculiar acid combined with potash, but in such a manner, that the acid is in considerable excess.

The salt is known under the name of acidulous tartrite of potash, and the acid which enters into its composition is the tartaric. It is by the combination of this acid with potash, that the acidulous tartrite of potash, or cream of tartar is formed by solution, with subsequent filtration and evaporation.

Benzoic Acid.

21. Benzoic acid is found in the resin, called benzoin, in the balsam of Peru and some other substances of this kind. It is also found in urine and other animal substances. It is this acid, whose volatility is shown in page 285, article *Sublimation*.

Camphoric Acid.

22. Camphoric acid, is camphor oxygeneted to acidity. Camphor is a concrete essential oil, extracted by sublimation from a laurel which grows in China and Japan.

Gallic Acid.

23. Gallic acid is found in gall-nuts, bark of

trees, and in all those vegetables called astringents.

Succinic Acid.

24. Succinic acid is obtained from amber, and is therefore called also acid of amber.

Amber is a bituminous substance of a yellow colour, which is found chiefly on the sea-coast of Prussia. It takes a fine polish, and is used for various ornaments. It is strongly electrical.

Suberic Acid.

25. Suberic acid exists in cork. It reddens vegetable blues, and has the peculiar property of turning the blue solution of indigo in sulphuric acid, to green.

Phosphorous Acid.

26. When phosphorous is burnt slowly, and does not become completely saturated with oxygen, it forms phosphorous acid. Its salts are the phosphites.

Phosphoric Acid.

27. Phosphoric acid is phosphorous saturated with oxygen.

This acid is obtained from bones, which are composed of phosphate of lime, and gelatine. It may also be obtained by the rapid combustion of phosphorous in oxygen gas.

Bombic Acid.

28. Bombic acid is obtained from the silkworm. It is very little known.

Sebacic Acid.

29. Sebacic acid, called also the acid of fat, is obtained from the fat of animals. It is concrete, and soluble in water. It is sour, and without odour.

Laccic Acid.

30. Laccic acid lately discovered in a substance called white lac, is formed by certain insects of the coccus tribe.

Lactic Acid.

31. Lactic acid is found in the whey of milk. It is concrete, and liquefies in the air. It is sour and oxidates the metals.

Saccho-Lactic Acid.

32. Saccho lactic acid was discovered by Scheele, who obtained it by treating sugar of milk with nitric acid. It is also obtained by treating gum-arabic with nitrous acid.

Uric Acid.

33. Uric acid also called lithic acid is found in urinary calculi, and in human urine.

Prussic Acid.

34. Prussic acid is produced by exposing the horns, hoofs, and dried blood of animals, with an equal quantity of fixed alkali, to a red heat.

This acid united to iron forms that beautiful pigment called Prussian blue. From this salt the acid is frequently obtained, this being the least expensive mode. The pure acid is perhaps the most intense poison ever known: a glass rod dipped in it, was inserted into the mouth of a dog, who fell dead as if struck by lightning the instant it touched the poor animal's palate. The dog had been a remarkably strong one.

Pyroligneous Acid.

35. Pyroligneous acid is obtained by distillation from wood; it is sometimes called wood vinegar. This acid is said to preserve animal food for any length of time. The whole carcase of a sheep being immersed in it, was found, upon examination many months afterwards, to be perfectly free from any appearance of putrefaction. A leg of mutton, declared unsaleable by the butchers, being immersed in the pyroligneous acid a twelvemonth ago, is stated to be at this time perfectly sweet, and likely from its appearance to continue so many years.—*June*, 1819.

Questions for Examination.

1. 2. Define an acid, enumerate the chief acids, and describe the sulphurous, and sulphuric acids.
3. 4. Also the nitrous and nitric acids.
5. 6. Also the muriatic and chloric acids.
7. 8. Describe the carbonic and fluoric.
9. 10. 11. Also the boracic, arsenious and arsenic.
12. 13. 14. Also the tungstic, molybdic, and chromic.
15. 16. 17. Also the columbic, acetic and malic.
18. 19. 20. Also the oxalic, citric and tartaric.
21. 22. 23. Also the benzoic, camphoric and gallic.

24. 25. 26. Also the succinic, suberic and phosphorous.
27. 28. 29. Also the phosphoric, bombic and sebaccic.
30. 31. 32. Also the laccic, lactic and saccho-lactic.
33. 34. 35. Also the uric, prussic and pyroligneous.

Section XIV.

Vegetable Substances.

Complex compounds are divided into vegetable, animal, and mineral substances. The mineral have been considered under Mineralogy and Geology. Vegetables and animals are living and organized beings: but they differ in these and other respects; vegetables which we shall treat of in this section are fixed to the earth, and cannot of themselves change their situation; animals possess loco-motive power which nature compels them to exercise, in searching for food for the preservation of their existence.

The most marked difference between animals and vegetables is that of food. Vegetables feed entirely upon inorganic substances, such as salts, earths and airs; whilst animals feed on organic matters, such as animals and vegetables.

Almost all vegetables are composed of three principal parts, the bark, or exterior covering, the wood, the woody fibre, which in trees constitutes the principal part; and the pith, which corresponds to the marrow of animals.

The general constituent principles of vegetables consist of hydrogen, carbon, oxygen, &c. though these do not exist in them in a simple and

uncombined state, but joined in various proportions, forming compound substances, that make up the whole vegetable.

The following are the principal substances met with in vegetables :

1. Mucilage
2. Fixed and volatile oils
3. Resin
4. Gum resins
5. Caoutchouc
6. Camphor
7. Wax
8. Honey
9. Sugar
10. Gluten
11. Fecula
12. Tannin
13. Woody Fibre
14. Colouring matter
15. Acids
16. Miscellaneous substances
17. Amber, and
18. Asphaltum are also supposed to be of vegetable origin.

Mucilage.

1. Various parts of vegetables impart to water, if boiled with them, a certain viscous matter causing consistency. This is called mucilage.

Some trees suffer their mucilage to transude, either spontaneously, or by incisions made in them. When it has become concrete by drying in the air, it is called gum. In this way gum arabic, gum senegal and cherry tree gum are formed.

Mucilage is without taste ; soluble in water, but not in oils or alcohol. It is not changed by exposure to the air.

From the experiments of Cruikshank, it appears to consist of oxygen, hydrogen, nitrogen, carbon, and lime.

Fixed and Volatile Oils.

2. Oil is composed of carbon and hydrogen; with a small portion of oxygen.

Oils are divided into fat or fixed oils, and volatile or essential oils. Fixed oil is usually obtained by expression, chiefly from the seed and kernels of plants.

Volatile oil is procured by distilling aromatic plants with water.

Resins.

3. Resins exist in the vessels of certain trees, and frequently exude from them spontaneously.

Sometimes they are procured by making incisions in the trees, and sometimes by distilling the wood. They are considered as volatile oils combined with oxygen. They are soluble in alcohol and oils, but not in water. It is this property that renders them so valuable as varnishes. They are very inflammable, and melt with a slight heat. The principal resins are the turpentine, the guaiacum, mastic, copal and sandarac.

Gum Resins.

4. Gum resins appear to be a natural mixture of resin and mucilage. They are partly soluble in water, and partly in alcohol. Gum ammoniac, assafœtida, and opium are gum resins.

Caoutchouc.

5. Caoutchouc, elastic gum, or Indian rubber, resembles a resinous gum. It is elastic, inflammable, and insoluble in water or fat oils. It is partly soluble in volatile oils, and entirely so in nitric ether.

It is the juice of a tree of the euphorbia tribe. When first exuded, it is of a milky consistence and colour, but it gradually thickens and is blackened by smoke.

Camphor.

6. Camphor, a volatile oil, is extracted from a species of laurel which grows in China and the East Indies.

It is very inflammable, and sublimes by a gentle heat. It is soluble in either alcohol, the oils, and acetic acid. It is highly odorous, and prevents the spreading of contagious disorders.

Wax.

7. Wax a vegetable substance, found in the greatest quantity on the anthers of flowers, and collected by bees, is insoluble in water and alcohol, but soluble in volatile and fixed oils. It is very inflammable. Its components are the same as those of volatile oils.

Honey.

8. Honey is formed chiefly in the pistils or female organs of flowers, whence it is collected by the bees: it appears to be sugar dissolved in mucilage.

Sugar.

9. Sugar is produced in the greatest quantity from the sugar-cane, but it may also be obtained from the sugar-maple, the beet-root, carrot, &c. Its constituents are oxygen, carbon, and hydrogen.

Gluten.

10. Gluten, an elastic viscid substance, is found in vegetables, and chiefly in wheat flour; it is soluble in water, and very slightly so in alcohol.

Fecula.

11. Fecula, or starch, forms the principal part of the substance which is washed away in order to obtain the gluten from the grain. When the fluid is suffered to stand, a white powder subsides, which is the starch. It is also obtained from potatoes.

Tannin.

12. Tannin matter is found in the gall-nut, the bark of oak trees, and other astringent parts of vegetables.

Woody Fibre.

13. Woody fibre constituting the basis of wood, may be procured separate from every other substance, by boiling wood-shavings in water to dissolve the extractive matter, and then in alcohol to separate the resins, &c.

Colouring Matter.

14. Colouring-matter is found in vegetables combined with, 1. the extractive principle; 2, with resins; 3, with fecula; 4, with gum. See the article Dyeing, " Elements of Science and

Art," under the title "Arts of Domestic Comfort."

Acids.

15. The acids which exist ready formed in vegetables, are the citric, malic, oxalic, gallic, benzoic, tartaric, acetous, and suberic. They have been already described.

Various Substances.

16. Besides the substances already enumerated, many others are found in vegetables, such as sulphur, iron, manganese, lime, alumine, magnesia, barytes, &c.

All the vegetables called gramina, or grasses, have an epidermis or outer skin, composed of silex. This is particularly observable in canes, which, when struck together in the dark, produce sparks of fire.

All the substances under this head have already been described.

Questions for Examination.

1. Of what do all vegetables consist? what are their constituent principles?
2. What is mucilage? Define fixed and volatile oils.
3. 4. Also resins, and gum resins.
5. 6. 7. Also caoutchouc, camphor, and wax.
8. 9. 10. Likewise honey, sugar, and gluten.
11. 12. 13. Also fecula, tannin, and woody fibre.
14. 15. Also colouring matter and acids.
16. What other substances have been found in vegetables?

SECTION XV.

Animal Substances.

1. The constituent principles of animal substances are nearly the same with those of vegetables; the former, however, contain more of nitrogen and phosphorus, the latter more of carbon and hydrogen.

The complex constituent parts of animal substances are the following:

1. Gelatine
2. Fibrine
3. Albumen
4. Animal oils
5. Bone
6. Blood
7. Milk
8. Horn
9. Phosphorus and animal acids.

Gelatine.

Gelatine, or animal jelly, very generally dispersed through all the parts of animals, even in bones, exists in the greatest quantity in the tendons, membranes, and the skin.

Fibrin.

2. Fibrin, or animal fibre, forming the basis of the muscular, or fleshy parts of animals, is fibrous in its structure, transparent, and insoluble in water and alcohol, except by a long continued heat in a Papin's digester.

Albumen.

3. Albumen is the principal constituent part of the serum of blood; it is also called coagulable lymph. The white of eggs consists almost entirely of albumen.

Animal Oil.

4. Animal oil, generally solid at the temperature of the atmosphere, contains more oxygen, and sebacic acid, than the vegetable oils.

Among animal oils may be ranked fat, tallow, lard, suet, butter, &c. Fish oil is generally more liquid than other animal oils. Spermaceti is an animal oil, found in the head of a species of whale.

Bone.

5. Bones consist chiefly of phosphate of lime, with carbonate of lime, and gelatine.

Blood.

6. Blood consists of albumen, fibrin, colouring matter, and a mild oil. The colouring matter has been supposed to depend upon iron, but Vauquelin has proved that the most delicate test could not prove the existence of iron in it.

Blood, when suffered to rest, separates into two parts, the one, a coagulum or clot, called the crassamentum, the other a fluid, called the *serum*.

Milk.

7. Milk if suffered to rest, throws upon its surface a butteraceous oil, called cream. If the remaining skimmed-milk be suffered to stand, it

becomes sour, and separates into two parts; curd, which is chiefly albumen; and whey (which is nearly analogous to serum,) mixed with sugar and lactic acid.

Horn.

8. Nails, horns, hoof, and quills, resemble coagulated albumen.

Phosphorus and Acids.

9. The animal acids and phosphorus have been already described. Many other animal substances, such as bile, urine, saliva, &c. are very complicated.

Questions for Examination.

1. What are constituent parts of animal substances? and of these describe gelatine.
2. 3. Describe also fibrin and albumen.
4. 5. Also animal oil and bone.
6. 7. Also blood and milk.
8. 9. Likewise horns, nails, phosphorus, and acids found in animals.

SECTION XVI.

Various Kinds of Fermentation.

These are, 1. The vinous; 2. The acetous; 3. The panary; 4. The putrid.

Vinous Fermentation.

1. If mucilaginous saccharine vegetable sub-

stances under a due combination with water and heat (from 60 to 70 deg. Fahrenheit), be not entirely excluded from air, they soon experience a striking change. An internal commotion takes place, air-bubbles are discharged from the inner part, and, on account of the toughness of the matter in which these bubbles are inclosed, they form a stratum on the surface of the fluid, known by the name of yeast. These bubbles consist of carbonic acid gas.

At length these appearances cease: the fermented liquor becomes clear and transparent, and no more gas is disengaged; the liquor has now lost its sweetness and viscidity, and acquired a vinous taste and intoxicating qualities.

Acetous Fermentation.

2. When wine, or any fermented or vinous liquor is exposed to a heat, from 75° to 80° Fahrenheit, and access of air is permitted, the fluid becomes torpid, a new change of principles takes place; it loses its taste and smell, becomes sour, and is converted into vinegar.

Panary Fermentation.

3. This is the fermentation produced by the action of yeast or flour and water in the making of bread.

Putrid Fermentation.

4. This is the last change or final decomposi-

tion of vegetables. Without moisture, heat, and a due access of air, this decomposition does not take place. In this state of fermentation, ammonia is evolved, accompanied by a very offensive smell. Vegetables which contain albuminous matter and gluten, are most liable to putrefaction.

Animal Putrefaction.

5. Every animal body, when deprived of life, and and exposed to the air, undergoes a decomposition, or resolution of its parts. Its colour becomes pale, and then changes to blue and green; the parts become soft, and send out a fetid smell, arising from the disengagement of a very noxious gas. The organization is destroyed; the constituent parts of the animal substance form new arrangements, and are chiefly resolved into the gaseous state. What remains is a dry powder, consisting of a mixture of earths and charcoal.

Questions for Examination.

1. Define and illustrate vinous fermentation.

2. 3. 4. 5. Also the acetous, panary, and putrid fermentation, and animal putrefaction.

SECTION XVII.

Meteorology.

Whatever is engendered in the air, which surrounds us, is a meteor. This word signifies a body raised above the earth that we nhabit.

Meteors are composed of vapours and exhalations. Vapours are particles of water which mingle with the air.

Exhalations are particles of all the different terrestrial bodies, which rise into the air, such as sulphur, salts, bitumen, and other bodies of different natures, more or less combustible, solid, or heavy.

Winds, mists, clouds, rain, dew, snow, and hail, are the meteors most familiar to us, and which we shall here describe.

1. Winds are bodies of air which press against other bodies of the same fluid: these second bodies in their turn press against others, and so on. This pressure from that part upon another, causes an accumulation of motion and force. Terrestrial bodies in resisting this pressure of the air are sometimes driven from their situations. The hurricanes in the West India Islands exemplify this well.—See Pneumatics.

Mists.

2. Mists are those collections of vapours, which chiefly rise from fenny moist places, and become more visible as the night comes on, and as the cold increases.

Clouds.

3. Clouds are collections of moist particles, exhaled from the sea and earth by the heat of the sun, and suspended aloft in the air.

The height of the clouds is supposed to be from about a quarter of a mile to a mile. It is common for persons, by climbing very high mountains, to get above the clouds, and see them swim beneath them.

The wonderful variety in the colour of the clouds, is owing to their particular situation with regard to the sun, and the different reflections of his light. The different figures of the clouds result from their loose and voluble texture, revolving into any form according to the varied force of the winds.

Rain.

4. Rain is a condensation by cold, of thick clouds, which, by their own weight, fall upon the earth in small quantities, called drops of water or rain.

Those small clouds, sometimes seen very high, and heaped upon one another, presage rain very soon.

When the horizon, at the rising or setting of the sun, appears pale and yellowish, it is a sign of the air being full of vapours, and threatens bad weather. But when it is of a light red at those times, there are but few vapours in the air, and fine weather may be expected.

The quantity of vapour evaporated at any degree of heat or wind depends on the quantity of vapour already in the atmosphere.

From experiments at Liverpool, it appears that the mean annual evaporation from the surface of water amounted to 36.78 inches. The proportion for every month was the following :—

	Inches.		Inches.
January - - - - -	1.50	July - - - - - -	5.11
February - - - -	1.77	August -- - - -	5.01
March - - - - -	2.64	September - - -	3.18
April - - - - - -	3.30	October - - - -	2.51
May - - - - - -	4.34	November - - -	1.51
June - - - - - -	4.41	December - - -	1.49

Mr. Dalton found the evaporation from the surface of water in one of the driest and hottest days of summer rather more than 0.2 of an inch.

Dew.

15. Dew is produced from a quantity of particles of water extremely subtile, that float about in a calm and serene air in the form of vapours, which, being condensed by the coldness of the night, lose by degrees their agitation, and many uniting together, fall in the morning in small invisible particles, like an extremely fine and delicate rain, that continues but a short time, and is seen in drops of water like pearls, upon leaves and herbs :—

Snow.

6. Snow is produced thus. In winter the regions of the air are intensely cold, and the clouds finding this great cold on every side, quickly pass from that state of condensation which might reduce them to rain, into that which is able to reduce them to ice; so that in winter, as soon as the clouds begin to change into very fine drops of water, each of these small particles freezes, and touching each other, they form flakes of snow.

The small intervals that the flakes leave between, like so many pores, filled with a subtile air, are the cause of their lightness.

The snow is white, because the small particles of ice, which compose those flakes, being hard, solid. transparent, and differently arranged, reflect to us the light from all parts.

Red Snow.

7. Our readers must all have heard of the red snow stated to have been found by our northern

navigators lying upon the surface of snow lodged in ravines, for upwards of 100 miles along the coast of Baffin's Bay. Quantities were collected and brought home in bottles; that is, the colouring substance, and the water of the snow on which it lay.

Dr. Thompson has published the result of experiments made upon small quantities of the colouring substance. On opening a phial of what had been collected, an offensive smell, similar to that of putrid sea weed, or excrement, was perceptible. After some time the colouring matter subsided, leaving the water colourless. Examined with a magnifier it appeared to consist of minute particles, somewhat globular, of a brownish red-colour.

Hail.

8. Hail is formed, when the parts of a cloud, beginning to fall, meet in their descent a very cold air, which freezes them, and these small bits of ice are very near the figure and size that the drops of water would have been, had they fallen.

Meteors.

9. A brilliant meteor was observed at Ipswich on the 8th of January 1818, about one o'clock in the morning. A fiery body was perceived resembling a red hot ball of iron 4 or 5 inches in diameter; which burst into a spherical body of white light nearly as large as the full moon, and of so great lustre as scarcely to be born by the eyes, throwing out a tail about 3 degrees in length of a beautiful rose colour, tinged round the edges with blue. It disappeared with an explosion or rumbling noise resembling cannon discharged at a distance, about 10 or 12 seconds afterwards. Its duration was about 5 seconds, during which it traversed a space of nearly 60 degrees.

Aerolites.

10. A remarkable phenomenon took place at Gerace in Calabria on the 13th March, 1813. The circumstance is related by Professor Sementini of Naples. The wind was westerly, and heavy clouds over the sea were approaching the land. About two hours after noon, the wind fell, and the sky became quite dark. The clouds assumed a red and threatening appearance, thunder followed, and rain fell, which had a red colour from a mixture of red dust. The inhabitants were alarmed, and flocked to the churches, conceiving that the end of the world was come. The red dust was very fine; it became black when exposed to a red heat, and effervesced when treated with acids. Its constituents were *Silica, Carbonate of Lime, Alumina, Iron, and Chromium.* What renders this rain the more remarkable is, that the constituents of this red dust are the same nearly with one of the varieties of Meteoric Stones.

Sir H. Davy thinks, that what are called falling stars, are not gaseous meteors in a state of combustion, but solid ignited masses moving with great velocity in the upper regions of the atmosphere.

Questions for Examination.

1. Of the meteors describe the winds.
2. 3. Also mists and clouds.
4. 5. Also rain and dew.
6. 7. 8. Likewise snow, red snow, and hail.
9. 10. Also meteors and aerolites.

CHAPTER XIV.

ELECTRICITY.

General Principles.

1. ELECTRICITY is a term used to denote the operation of a very subtle fluid, in most cases invisible, but which sometimes becomes the object of our senses, proving itself to be one of the principal agents employed in producing the phenomena of nature.

2. The following is a list of *electrics* and also of *conductors*, disposed according to the order of their perfection, beginning in each column with the most perfect of their class. Thus, *glass* is a more perfect *electric* than *amber*, and *gold* is a better *conductor* than *silver*.

Electrics.	*Conductors.*
Glass of all kinds.	All the metals in the following order:
All precious stones, the most transparent the best.	Gold, silver, platina, brass
Amber	Iron, tin, quicksilver, lead
Sulphur	The semi metals
All resinous substances	Metallic ores
Wax of all kinds	Charcoal
Silk and cotton	The fluids of the animal body

Dry external animal substances, as feathers, wool and hair.
Paper
Loaf sugar
Air, when dry
Oils and metallic oxides
Ashes of animal and vegetable substances
Most hard stones

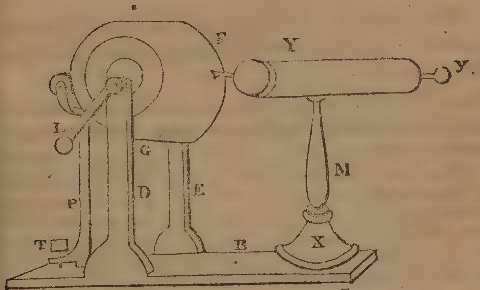
Water, especially salt water, and other fluids, except oil
Ice, snow
Most saline substances,
Smoke, steam, and even a vacuum.

Questions for Examination.

1. What is electricity?
2. Give me a list of the chief conductors and electrics.

SECTION I.

Of the Electrical Machine.



1. This diagram is a representation of an electrical machine with a prime conductor. A B C represents the bottom board of the machine, D

and E the two perpendicular supports, which sustain the glass grinder F G. The axis of the cap K passes through the support D: on the extremity of this axis a simple winch, L, is fixed.

The axis of the other cap runs in a small hole, which is made in the top of the supporter F. P is the glass pillar to which the cushion is fixed; T a brass screw at the bottom of this pillar, which is to regulate the pressure of the cushion against the cylinder. This adjusting screw is particularly advantageous; as by it, the operator is enabled to lessen or increase gradually the pressure of the cushion, which it effects in a much neater manner than it is possible to do when the insulating pillar is fixed on a sliding board. Y represents the positive prime conductor, or that which takes the electric fluid immediately from the cylinder; M the glass pillar by which it is supported and insulated, and X a wooden foot or base for the glass pillar.

The following statement seems to comprise the general principles on which this wonderful fluid is known to act:

2. The *electric fluid* is probably the same in essence with that of light and heat, but combined with a substance which affects the organs of smell.

When bodies are electrified by glass they furnish tufts or pencils of light; but if electrified by sulphur, they only produce points or sparks of light; bodies presented to those electrified by glass produce only luminous sparks; while those which are presented to bodies which are electrified by sulphur present beautiful pencils or tufts of light.

3. Bodies are electrified either by *friction*, or *communication*. To electrify bodies by communication, it is necessary to insulate them: and

the substances the most proper for insulating others, are those which electrify best by friction.

Glass, however, though it *electrifies* very well by *friction*, electrifies also by *communication*, even without any preliminary preparation; yet it is very proper for insulating.

4. The electrical matter is not produced entirely from the bodies upon which the electrifying machine acts; the *adjacent bodies*, or substances *contribute* towards its production.

5. The *energy* of the electric virtue is *augmented*, in conductors, more by an *increase* of *surface*, than by an augmentation of mass. Electrified bodies *adhere* to one another, so that, on some occasions they cannot be separated without a considerable effect. Electricity *accelerates* the evaporation of liquids and the respiration of animals.

The *pencils* or tufts of light, which are seen at the extremities or angles of electrified bodies, are always composed of divergent rays when they pass through the air; but if a non-electric, or conducting body is presented to them, they lose a great deal of their divergency; their rays become sometimes even convergent, in order that they may approach towards that body which is more permeable than the air; and if they are made to pass into a *vacuum*, they will assume the form of a large branch of light nearly cylindrical, or in the form of a spindle.

Questions for Examination.

1. Describe the electrical machine.
2. What is the electric fluid supposed to be the same as? And how is this known?
3. How are bodies electrified?
4. Do adjacent bodies contribute towards the production of the electrical fluid?
5. What other phenomena do you observe of this fluid?

Section II.

Of the Electric Spark.

The spark that shines between the two bodies, is capable of setting *combustible* matters on fire.

1. If a body, containing only its natural share of electricity, be presented sufficiently near to a body electrified, *positively* or *negatively*, a quantity of electricity will force itself through the air, from the latter to the former, appearing in the form of a *spark*.

2. When two bodies approach each other sufficiently near, one of which is electrified *positively*, and the other *negatively*, the superabundant electricity rushes violently from one to the other, to restore the equilibrium between them. This effect takes place, if the two bodies be connected by a conducting substance.

3. The electric spark has not only the appearance of fire, but is capable of actually setting fire to various substances that are easily inflamed.

4. The senses of feeling, seeing, and hearing, are not only affected by electricity, but it is even sensible to the smell and the taste.

5. The electric spark goes to a greater or less distance through the air, in order to reach a conductor according as its quantity is greater or less; as the parts from which it proceeds, and on which it strikes, are sharper or more blunt, and as the conductor is more or less perfect. The strength of the machine is known from the length and density of the sparks it gives.

Questions for Examination.

1. What is the electric spark?
2. When does this effect take place?
3. What appearance does this spark have?
4. How does it affect the senses?
5. How does it move, and what does its strength or density prove?

Section III.

Electrical Instruments on Apparatus and Experiments.

1. The experiments in electricity are so various, that the apparatus may be increased almost agreeably to every man's fancy; and in general he who wishes to make new experiments, will find it necessary to make an addition suitable to the object of his enquiry. It will be, therefore, most consistent with the design of this work, to describe only those parts of the apparatus, which are most essential to the performance of the most popular experiments.

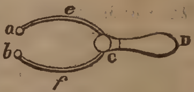
2. The instruments commonly employed in this branch of science may be classed under six heads: 1st, The instruments used for *exciting* electricity, viz. *glass tubes*, plates, and cylinders; 2nd. Those for *conducting* the electric matter which are chiefly METALS; 3rd, Those intended for *accumulating* the fluid, or in technical language for *receiving a charge*, such as coated bottles or jars, commonly called LEYDEN PHIALS; 4th, Those which are intended to *produce more formidable effects*, such as ELECTRIC BATTERIES; 5th, The instruments employed for *ascertaining the quantity of electricity*, called ELECTROMETERS; and lastly, those employed for *retaining* the electric power.

1. Of the first class of these instruments we have treated in explaining the electrical machine and first principles of electricity.

2. The nature and uses of such conductors as are attached to the machine, are usually explained along with it; any instrument which serves to convey the electrical influence from one body to an other, may be regarded as a *con-*

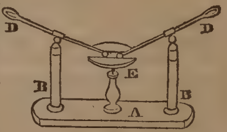
ductor. With this view, wires and chains are employed to form a communication between different bodies; and under this head we may also class the common discharging rod, (fig. C D E, as below,) the principle of which consists in a curved and jointed rod of metal, with knobs at the ends; and furnished with a glass handle, to prevent the electric shock from passing through the body of the operator.

The Discharging Rod.



3. D is the glass handle cemented into the brass socket; *e*, *f* are brass wires, which are curved, and may be opened by the joint to any extent required. The wires are pointed, as it is sometimes necessary to draw off a charge that way; and the knobs *a*, *b*, are made to screw on the end of the wires. It is most frequently used with the knobs, particularly in discharging large jars and batteries.

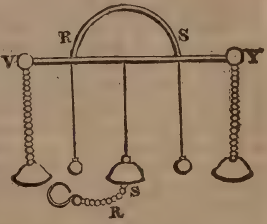
The Universal Discharger.



4. The *universal discharger* consists of two wires supported by glass feet, with a small table between them, to support any thing that may be the object of experiment. It is a very useful instrument for a variety of purposes, and is composed of the following parts, viz.: A is a flat board, about fifteen inches long, four wide, and one thick. B, B are two thick glass pillars, cemented in four holes upon the board A, and furnished at top with brass caps, each of which has a turning joint, and supports a spring tube, through which the wires D, D slide. Each of the caps is composed of three pieces of brass, connected so that the wires D, D, besides their sliding through the socket have a horizontal and vertical motion. Each of the wires D, D is furnished with an open ring at one end, and at the other it has a brass ball, which, by a short spring

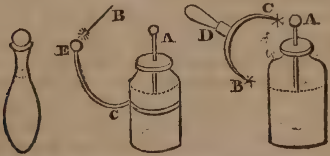
socket, is slipped upon the pointed extremity, and may be removed. E is a circular piece of wood, having on its surface a slip of ivory inlaid, and supported on a stand.

The Electrical Bells.



5. This apparatus consists of three small bells suspended from a narrow plate of metal, the two outermost by chains, and that in the middle (from which a chain, S R, passes to the floor) by a silken string. Two small knobs of brass are also hung by silken strings, on each side of the bell, which serve as clappers. If an apparatus of this kind is joined to one of those conducting rods erected to protect buildings from the effects of lightning, it will serve to give notice of the approach and passage of an electrical cloud.

Of the Leyden Phial.



6. This instrument is represented in the two right hand figures of the above diagram. Place the jar on a table or any other non-electric body which communicates with the earth, and let the ball on the top be about one eighth of an inch from the ball of the conductor Y, page 375. If the machine is turned, sparks may be perceived passing from the ball of the

conductor to the ball A of the jar. When this effect ceases, and no more sparks are to be perceived to pass from the conductor, the jar may be considered as charged, the inside positively and the outside negatively. To discharge the jar all that is necessary is to form a communication between the outer and the inner coating of the jar or phial, that the surplus of the fluid may be conveyed from the one to the other. To avoid the painful sensation which is the consequence of the shock, this may be performed by the discharging rod, as shewn in the figure.

The operator should hold the rod by the glass handle, D, and place one knob B close to the outer coating, and then bring the other knob C near the ball of the jar; the jar will be discharged with an explosion proportioned to the quantity of electricity it had received. If, when the jar is charged, a person touches the outside with one hand, and brings the other near the knob of the jar, he will then receive the shock. A chain is sometimes concealed under the carpet, connected with the outside coating, and another is connected with the top of the jar; and if a person standing on one, is incautiously induced to put his hand on the other chain, he will receive a shock to his great surprise, and the entertainment of the company; but care should be taken that the shock in this case be rather weak than otherwise.

That the charge of a coated jar resides in the glass, and not in the coating, is proved in the following manner: set a plate of glass between two metallic plates, about two inches in diameter, smaller than the plate of glass; charge the glass, and then remove the upper metallic plate; by an insulated handle, take up the glass plate, and place it between two other plates of metal which have not been electrified, but insulated—the plate of glass thus coated afresh will still remain charged.

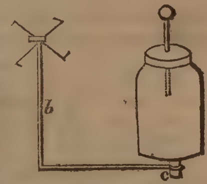
7. The following experiments are further illustrative of the nature of the Leyden phial:

1. *A cork ball*, or an *artificial spider* made of burnt cork, with legs of thread, will play between the knobs of

two bottles, one of which is charged positively, and the other negatively, and will, in a short time, discharge them. (See the fig. page 389.)

2. *A ball suspended on silk*, and placed between two brass balls, one proceeding from the outside, the other from the inside of a Leyden jar, when the bottle is charged, will fly from one knob to the other, and by thus conveying the fluid, from the inside to the outside of the bottle, soon discharge it.

3. An *insulated cork ball*, after having received a spark, will not play between, but be equally repelled by two bottles, which are charged with the same power.



A wire is sometimes fixed to the under part of the insulated coated phial, and *b c* is another wire fitted to the former, and at right angles with it; a brass fly is placed on the point of this wire. Charge the bottle. All the time the bottle is charging the fly will turn round. When it is charged, the motion will cease. If the top of the bottle is touched with the finger, or any other conducting substance, the fly will turn again till the bottle is discharged. The fly will electrify a hair or ball *positively*, while the bottle is charging, and *negatively*, while it is discharging.

4. When a Leyden phial, positively charged, is insulated, it will give sparks from its knob to an excited stick of wax, but not a spark will pass at that time between it and an excited glass tube.

An additional quantity of the fluid may be thrown on one side of the jar, if by any contrivance an equal quantity be made to escape from the other, and not otherwise.

Questions for Examination.

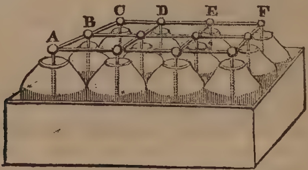
1. Of what importance are the electrical experiments?
2. What are the instruments used in these experiments?
3. Describe the discharging rod.

4. Also the universal discharger.
5. Also the electrical bells.
6. Also the Leyden phial.
7. What experiments may be performed with the Leyden phial?

SECTION IV.

The Electric Battery.

1. Electricians, in order to increase the force of the electric explosion, connect several jars, or Leyden phials together in a box, and this is called an electric battery.



The above figure is a battery composed of twelve jars, coated inside and outside with tin foil, containing about twelve feet of coated glass. About the middle of each of these jars is a cork sustaining a wire, knobbed at each end, which connects the inside coating of three jars, and by four wires, such as A, B, C, D, the inside coating of all the twelve jars may be connected together. The square box that contains these jars is made of wood, lined at the bottom with tin foil, and has two handles on two opposite sides, by which it may be more easily carried. In one side of the box is a hole through which an iron hook passes, which communicates with the lining of the box, and consequently with the outside coating of all the jars. To this

hook is fastened a wire, the other end of which is connected with the discharging rod.

When a battery is to be charged, instead of a large prime conductor, a small one is much more convenient; for in this case, the dissipation of the electricity is not so considerable.

Obs. The *quadrant electrometer*, hereafter to be described, which shews the height of the charge in the battery, may be fixed either upon the prime conductor or upon the battery, in which case it should be attached to a rod proceeding from the wires of the jars; and if the battery is very large, it should be elevated two or three feet above them.

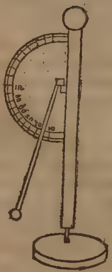
The index to the electrometer, in charging a large battery, will seldom rise so high as 90°, because the machine cannot charge a battery so high in proportion as a single jar.

Its limits are often about 60° or 70°, more or less, in proportion to the size of the battery and the force of the machine.

If a battery be discharged through a small steel needle, it will, if the charge is strong, communicate magnetism to it. If the discharge of a battery is passed through a small magnetic needle, it will destroy the polarity of the needle, and sometimes invert the poles, but it is often necessary to repeat this several times.

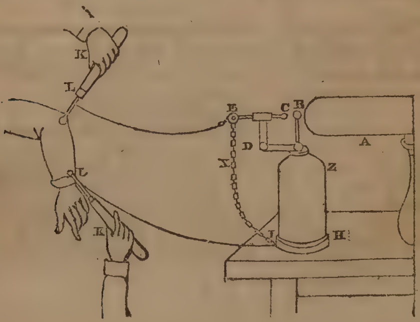
The instruments for ascertaining the presence and the quantity of electricity in different bodies are various.

2. The simplest of all are a pair of little balls of cork, or rather of the pith of elder, which is still lighter, and suspended by silk threads. When brought into contact with an electrified body, the balls will immediately diverge, and according to the degree of divergence, a judgment may be formed of the degree to which the body in question is electrified. A similar effect will be produced by a light and downy feather. The pith balls are called *Canton's electrometer.*



3. For more particular admeasurement, that is, for ascertaining precisely the degree to which any body is electrified, an instrument somewhat less simple is required, and the *quadrant electrometer* is in most general use. It consists of a perpendicular stem formed at top like a ball, and furnished at its lower hand with a brass ferule and pin, by which it may be fixed in a hole made in the conductor of the *electrical machine* or of a *Leyden jar*. To the upper part of the stem a graduated ivory semicircle is fixed, about the middle of which is a brass arm or cock, to support the axis of the index. The index is a very slender stick, which reaches from the centre of the graduated arch to the brass ferule, and to its lower extremity is fastened a small pith ball, nicely turned in a lathe. When this electrometer is in a perpendicular position, and not electrified, the index hangs parallel to the pillar; but when it is electrified, the index recedes more or less, according to the quantity of electricity.

4. Lane's discharging electrometer, as it is commonly called, is employed chiefly by the practitioners of medical electricity.



It is represented by C D E, and is fixed to the wire that proceeds from the inside of the jar Z. The ball B touches the prime conductor A, which is supposed to stand before an electrical machine. The electrometer consists in a glass rod F D, furnished with brass caps F D; from the latter proceeds a strong brass wire, to which is an horizontal spring socket; through this the wire C E, having the ball cap on one end, and the open ring E at the other, may be slided backwards or forwards, so as to place the ball C at any required distance from the ball B. Suppose the distance between B and C to be one-fourth of an inch or less, and that by means of a chain X, a communication be formed from E to the outside coating of the jar. When the jar is charged so high that the fluid can leap from B to C, the discharge will take place, and the stroke pass through from the inside to the outside of the jar. When the shocks are to be given through any part of the body, as the arm, then instead of the chain X, wires E L and I L, are to be fastened, one to the ring E, and the other to the hook at I, of the stand, H I, which communicates with the outside of the jar. The other extremities of the wire must be fastened to the directors K L, which consist of brass wires and balls as L, fastened into brass handles, K, (see also the annexed cut.) The mode of operation is easily understood from a view of the figure; for when the chain X is away, the electric fluid must, in passing from the inside of the jars to the outside, go

through the wire E L, the brass of the director, the part of the arm between the balls of the directors, and through the wire L I. By moving C nearer to or further from B, the strength of the shock will be regulated to any degree.

Several instruments have also been invented for ascertaining the state of the atmosphere with respect to the quantity of electricity it may contain at any given time. The best of them are improvements on Canton's electrometer, which is made by enclosing the pith balls, or rather

two slips of gold, in a cylindrical glass vessel, to prevent their being affected by the wind.

Questions for Examination.

1. Describe the electrical battery.
2. What instruments are there for ascertaining the presence and quantity of electricity in different bodies ?
3. Describe the quadrant electrometer.
4. Describe Lane's discharging electrometer.

SECTION V.

Electrical Phenomena, and Experiments.

1. The various phenomena of electricity may be divided into four classes, in the first of which may be included all those experiments which serve to illustrate electrical attraction and repulsion; in the second those produced by the stream of electricity; in the third class may be ranged all those phenomena which are accompanied with luminous appearance; and, lastly, we may enumerate those more formidable effects arising from the concentrated electricity, in the experiments with the Leyden phial and the electrical battery.

2. *Experiment.* That *light* bodies are attracted and repelled by the electric influence, is evident from many common experiments.

If a downy feather be affixed by a linen thread to a small wire, and the wire inserted into the prime conductor, upon turning the cylinder, the plumage of the feather will expand in every direction, aud the threads also will recede from each other. If a finger approaches the feather, the plumage will bend towards it, and if the finger be moved, the feather will seem to follow it.

If a spark is taken from the conductor, the plumage will immediately collapse, but if the cylinder is again excited, the threads will diverge, and the plumage will expand as before.

Experiment

3. There is another very entertaining experiment illustrative of the electric attraction.

If a small plate of metal be suspended from the prime conductor; and another at a small distance under it; if upon the lower plate a piece of gold leaf be laid;—when the cylinder is turned, the gold will be lifted up, and expand itself with one corner opposite the upper, and the other opposite the under plate. If the room is darkened, the leaf gold will appear to be supported by pillars of fire.

The same Experiment with Figures.

4. If instead of the gold leaf, small figures or images made of thick paper, be placed on the under plate, upon turning the cylinder, the images will rise up in an erect position, and will seem to dance between the two plates sometimes leaping upon each other, and exhibiting a variety of entertaining positions. If the head of one of the images is held before the fire and dried, the image will ascend to the upper plate and remain there, and if the experiment is reversed, and the feet of the image are dried, and the head a little moistened at the same time, the image will continue to stand on the lower plate. This experiment will not succeed, if glass plates are used, because glass being electric, cannot transmit the electric matter; but if the finger or any conducting body be held under the glass plate, they will then move as before.

Experiment

5. There is another very pretty experiment illustrative of the same principle, the apparatus for which consists of three small bells with clappers between them, see the fig. page 381, *Article 5.*

If the machine be turned, the clappers fly from bell to bell, and ring a kind of peal by the effect of electricity. To explain this, it is necessary to notice that the two outer bells are suspended by metallic chains, and the middle bell and clappers by silk; but from the middle bell a chain is suspended, which goes to the tables. The fluid is conveyed from the conductor down the chain to the two exterior bells, and the clappers,which are light, are attracted, by them. The clappers becoming charged, are repelled by the outer bells, but attracted by that in the middle, to which they impart the electricity they had received, and it is conveyed to the earth, by the chain which communicates with the table. Being then disburthened, they are again attracted and strike the outer bells as before: and this action and re-action are continued as long as the machine is kept in motion.

Experiment

6. The electric porcupine, as it has been called, is formed nearly in the shape of the animal, the name of which it bears.

It is covered with ermine, or some other fur, in which are inserted some pieces of cotton pulled out to a considerable length, to resemble the porcupines quills. On turning the machine, the hairs of the fur or ermine diverge, and the pieces of cotton are discharged, and by a powerful conductor are driven some feet distance. This effect, it is obvious, depends upon the principle which has just been explained, and it is illustrative of the electric repulsion.

7. *Exper.* A very common mode of demonstrating the same effect, is to put a pointed wire into one of the holes of the conductor, and while the machine is in action to hold a glass tumbler over the point till its internal surface becomes charged. If then, a few pith balls are laid on the table, and covered by the tumbler, the balls will presently move about, as if by magic power.

That the stream of electricity is capable of producing

motion in almost a similar manner to the stream of common air, will be manifest from several pleasing experiments.

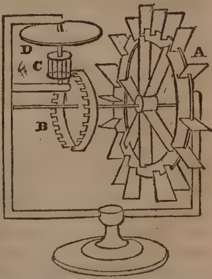
8. *Exper.* If a brass cross, or fly, such as that on the left hand side of the diagram, page 383, is placed on the conductor when the machine is turned it will go rapidly round. If it is taken off and held under the conductor, it will move in the same manner. If the cross, or fly, as it is called, be insulated, it will not move, because no electricity can be drawn through it either way. If a pin, or any other conductor, approaches it, it will move as usual.

9. *Exper.* By means of the stream of electricity issuing from a point, many other amusing experiments have been contrived, such as the *electrical Orrery,* shewing the motion of the sun, earth, and moon.

The sun and earth go round the common centre of gravity, and the moon round the earth in a lunar month, and these motions are represented by an electrical experiment.

10. *The Electrical Water Mill*

Represents a water mill for grinding corn, turned by a stream of electricity.



A is the *water*-wheel, B the *cog*-wheel on its axis, C the *trundle* turned by that wheel, and D the running *mill-stone* on the top of the axis of the trundle. It may easily be contrived, and turned also by electricity, if instead of the round plate D for the mill-stone, there is an *horizontal-wheel* on the trundle C with *spur-cogs,* which will turn two trundles placed on its opposite sides, and on the top of each axis of these trundles may be a round plate representing a mill-stone; so that this model has all the

working parts of a double water-mill turning two mill-stones.

To work this mill set it near the prime conductor, and place the crooked wire so that its point may be directed toward the uppermost side of the great wheel A. Then turn the glass globe by the winch, and the stream of the electric matter that issues from the wire will turn the wheel, and, consequently all the other working parts of the mill.

Experiment. Small aquatic boats or swans are sometimes made of light wood, or cork, and they may be attracted and made to swim in any direction, by applying a finger towards them; or they may have the addition of sails, and will then be made to sail briskly before an electric gale proceeding from a wire in the hands of the operator.

11. Every person knows that with his knuckle or finger, he can draw sparks from a conductor: the further he removes his knuckle from the conductor, the longer will be the spark, and it will even resemble lightning in the curves it forms, and its zigzag appearance. There is even a mode of imitating the course of lightning by some conducting substances, such as pieces of tin-foil pasted at certain distances on a plate of glass, and sending a strong spark through them from the prime conductor.

12. *The Spiral Tube*

Is a glass tube with pieces of tin foil pasted on at intervals of space

E  F

in a spiral direction. It is inclosed in a larger tube, fitted with brass caps at each end, which connect with the tin-foil. When the electric spark is made to pass through this tube, a beautifully illuminated spot will be seen at each separation of the tin-foil; and from the course in which the electric light is attracted, will serve to give some idea, on a very diminutive scale, of the manner in which lightning is attracted from one cloud to another.

13. *The Electrical Jar.*

Exper. A similar effect will be produced by the jar; and the diadem of beatification is an interesting experiment. The person who wishes to exhibit this experiment, binds his head with a band of silvered leather, and while he stands upon an insulated stool is connected with the conductor by a metallic chain. If then, while the machine is turned, another person passes his knuckle or finger near the band of leather, it will appear beautifully illuminated,' vivid flashes of lightning playing about the person's head who wears the diadem.

14. *To set Spirits of Wine on Fire.*

Exper. This experiment is easily performed, either by placing the ladle or spoon which contains the fluid upon the conductor, and taking the spark through the spirit, or by a person holding the spoon or ladle in one hand, while he stands upon the insulated stool, having the other hand on the conductor. If then another person approaches the spoon, either with his hand or with a poker, the spark will pass through the spirits of wine, and set it immediately in a flame. The experiment will succeed better if the spirit is a little warm, or even if the spoon in which it is contained has been previously heated.

Questions for Examination.

1. Into how many classes are the various electrical phenomena divided?
2. How is it proved that light bodies are attracted and repelled by electrical influence?
3. Describe the next experiment with gold leaf to illustrate electrical attraction?
4. Describe the same experiment with figures.
5. Describe the bell electrical experiment.
6. Also the electrical porcupine experiment.

7. Describe the tumbler and balls experiment.

8. How may a stream of electricity be made to put a machine in motion?

9. What is the principle of the electrical orrery?

10. Describe the construction and use of the electrical water-mill.

11. How does electricity resemble lightning in its zig-zag motion?

12. What is the spiral tube experiment?

13. Also the electrical jar one; and the diadem of beatification?

14. How do you set spirits of wine on fire?

SECTION VI.

1. *Concentrated Electricity.*

Concentrated electricity possesses considerably stronger powers than the spark, that is, when the fluid is accumulated by means of a Leyden phial, or a glass plate properly prepared.

2. *To Perforate a Card.*

Exper. If a card is held close to the coating of a charged jar, near the bottom, and one knob of the discharging rod is applied to it, and the other to the ball of the jar, the electric fluid will perforate it. The edges of the hole on each side will be a little raised, and the discharge will be attended with a sulphurous smell. With a moderate battery a quire of the thickest paper may be perforated in the same manner.

Exper. If a small chain is laid on a white sheet of paper and a shock from a Leyden phial is made to pass through it, the paper will be stained; having black tints at each joint of the chain; and if the experiment be made in the dark, the chain will be illuminated with a kind of radiation at every joint.

3. *To melt Metals.*

Exper. By a strong shock of electricity, metals are melted,

and gold may be incorporated with glass, so as to give it the colour and appearance of that metal. The experiment is not difficult. All that is required is, to take two narrow slips of common window-glass, each about an inch wide, and three or four inches long. Let a narrow slip of gold leaf be placed between the glasses with about an inch at each end hanging beyond the glasses, which should, by-the-bye, be pressed closely together; one end of the slip of gold leaf should communicate with the outer-coating of the phial; and when it is charged, one knob of the discharging rod must be applied to the other end of the leaf, so as to send the charge through it. When the glasses are taken asunder, the gold will be found to have been melted, and actually incorporated with the glasses, which consequently must themselves have undergone a partial fusion.

5. *To Kill a Plant.*

Exper. By a smart shock of electricity from a charged phial or a battery, a plant may be killed, and the experiment will best succeed with the common balsam.

6. *To augment the Evaporation of Fluids.*

Exper. Electricity augments the natural evaporation of fluids, and especially of those fluids which are of themselves most subject to evaporation; it has also a greater effect on fluids when the vessels containing them are *non-electrics.* Thus, if a humid body, a sponge, for instance, be placed upon a conductor positively electrified, the evaporation will proceed very rapidly, and it will dry much sooner than a similar body differently circumstanced.

Questions for Examination.

1. What is meant by concentrated electricity?
2. How may a card be perforated?
3. How may a chain be illuminated?
4. How may metals be melted?
5. How may a plant be killed?
6. How may the evaporation of fluids be augmented?

Section VII.

Miscellaneous Phenomena.

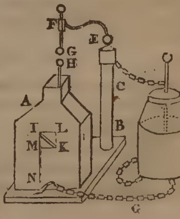
1. That electricity increases the perspiration of animals may be inferred from the circumstance that electrified animals are always lighter than those which are not.

2. The stream of electric fluid has no sensible heat, but appears even cold to the touch; yet we have seen that the more inflammable bodies, and particularly spirits of wine, may be inflamed by it; in this respect, it remarkably differs from fire or caloric.

3. The *luminous* effects of electricity are not the same in *vacuo* as in *air*; and the reason is this, that dry air is a non-conductor.

Exper. Thus, if a wire with a round end be included in an exhausted receiver, and presented to the conductor of an electrical machine, every spark will pass through the vacuum in a broad sheet of light, visible through the whole length of the receiver, moving with regularity, (unless it be turned back by some non-electric) and then dividing into a number of beautiful streamlets, which are continually separating and uniting in a most interesting manner. When the vessel is grasped by the hand, a pulsation will be observed like that of an artery, and the streams will incline towards the hand. A small quantity of air, however, is wanting to occasion the most luminous effects.

4. *The Thunder House.*



Exper. The effects of the electric matter, when it strikes a building, and the method of preventing it are exemplified by an instrument called the *thunder house*, representing the side of a house, either furnished with a metallic conductor or not. A is a board about three-quarters of an inch thick, and shaped like the gable end

of a house. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glass pillar C is also fixed, in a hole about eight inches distant from the basis of A. A small hole I L K M, about one-fourth of an inch deep, and nearly one inch wide, is made in the board A, and is filled by a square piece of wood of nearly the same dimensions, it being necessary that it should fit the hole, in order to drop out by the least shaking of the instrument. A wire I K, is fastened diagonally to this square piece of wood. Another wire L H, of the same thickness having a brass ball, H, screwed on its pointed extremity, is fastened on the board A, so also is the wire M N, which is shaped in a ring at N. From the upper extremity of the glass pillar C, a crooked wire proceeds, having a spring socket F, through which a double knobbed wire slips perpendicularly, the lower knob G of which falls just above the knob H. The glass pillar C must not be made very fast in the bottom board, but it must be fixed so that it may be easily moved round its own axis, by which means the brass ball G may be brought either nearer or farther from the ball H without touching the part E F G. Now when the square piece of wood L I M K, (which may represent the shutter of a window or the like), is fixed into the hole, so that the wire I K stands in direction L M, then the metallic communication from H to N is complete, and the instrument resembles a house furnished with a proper conductor; but if the square piece of wood L I M K is fixed, so that the wire I K stands in the direction I K, as represented in the figure, then the metallic conductor H N, from the top of the house to its bottom, is interrupted at L N, in which case the house is not properly secured.

Fix the piece L I M K, so that the wire may be as represented in the figure, in which case the metallic conductor H N is discontinued. Let the ball G be fixed perpendicularly about half an inch distance from the ball H M, only turning the glass pillar C, remove the former ball from the latter; by a wire or chain, connect the wire E F with the wire G of the jar P, and let another wire or

chain, fastened to the hook N, touch the outside coating of the jar. Connect the wire G with the prime conductor, and charge the jar; then by turning the glass pillar C, let the ball G come gradually near the ball H, and when they are arrived sufficiently near one another, the jar will be discharged, and the piece of wood L I M K will be pushed out of the hole to a considerable distance from the thunder house. The ball G in this experiment, represents an electrified cloud, which, when it arrives sufficiently near the top of the house A, discharges into it the electric fluid; and as the House is not secured by a proper conductor, the explosion breaks part of it, *i. e.*, knocks out the piece of wood I M.

Repeat the experiment; but let the piece of wood I M be so situated, that the wire I K may stand in the situation L M, by which the conductor H N will not be discontinued: in this case the explosion will have no effect upon the piece of wood L M, which shews the utility of metallic conductors for houses.

Variation in this Experiment.

Unscrew the brass ball H from the wire H L, so that it may remain pointed, and with only this difference in the apparatus, repeat these two experiments; the piece of wood L N will remain immoveable, and no explosion will be heard. The conductor E F G in this experiment is supposed to represent a thunder cloud discharging its contents on a weathercock, or any other metallic substance on the top of a building; hence it may be inferred, that if there is a metallic communication to conduct the electric fluid down to the earth, the building will receive no damage; but where the connection is imperfect, it will strike from one part to the other, and thus endanger the whole building.

Elevated conductors applied to buildings to secure them from lightning, will in this manner discharge the electricity from a cloud that passes over them and a greater quantity of the discharge will pass through a

pointed conductor than through one which terminates by a ball; but whether the discharge be made by a gradual current or explosion will depend on the suddenness of the discharge, on the distance or vicinity, and the motion of the cloud; also upon the quantity of electricity contained in it. If a small cloud hangs suspended under a large one loaded with electric matter pointed conductors on a building underneath will receive the discharge by explosion, in preference to those terminated by balls, the small cloud forming an interruption.

Questions for Examination.

1. How may it be inferred that electricity increases the respiration of animals?
2. How does electricity differ from fire or caloric?
3. How do you shew that the luminous effects of electricity are not the the same in vacuo as in air?
4. Describe the thunder-house and shew its use in experimental electricity.

SECTION VIII.

Electrical Meteorological Phenomena.

The success of Dr. Franklin in ascertaining the cause of thunder and lightning, has led subsequent philosophers to apply the same theory to the explanation of the other atmospherical phenomena.

From a number of observations, the indefatigable BECCARIA endeavours to account for the *rising of vapours* and *the fall of rain* upon electrical principles.

This philosopher supposes, that previous to the fall of rain, a quantity of electric matter escapes from the earth,

and in its ascent into the higher regions of the air collects, and conducts with it a great quantity of vapours. The same cause that collects will condense them more and more, till in the places of the nearest intervals, they come almost into contact, so as to form small drops, which uniting with others, as they fall, come down upon the earth in the form of rain. The rain he supposes to fall heavier in proportion as the electricity is more vigorous.

Hail he supposes to be formed in the higher regions of the air, where the cold is intense, and where the electric matter is very copious. Under these circumstances, a great number of particles of water are brought near together, where they are frozen; and in their descent collect other particles, so that the density of the substance of the hail-stone grows less and less, from the centre; this being formed first in the higher regions, and the surface being collected in the lower. Agreeably to this theory, it is observed that on mountains, hail-stones, as well as drops of rain, are small, there being but a small space through which they can fall.

Clouds of snow differ from clouds of rain only in the circumstance of the cold which freezes them. Both the regular diffusion of snow, and the regularity of the parts of which it consists, shew the clouds of snow to be actuated by some uniform cause like electricity.

Consistent with this theory is the fact, that *vapours* never rise to a great height without producing *meteors*. Almost all *volcanic* irruptions are accompanied by *lightning*. The column of vapour which proceeds from the bowels of a volcano is continually traversed by lightning which sometimes seems to proceed from the higher regions, sometimes from the columns itself. These lightnings were observed by the younger Pliny in the irruption which killed his uncle; and Sir William Hamilton has observed them several times.

The *aurora borealis* is also generally supposed to be an electrical phenomenon. Its light seems to proceed from

the electric fluid, while it is condensed in passing in the columns of elevated vapour.

The appearances of the aurora borealis come under four different descriptions. 1st. An horizontal light, like the morning aurora, or break of day. 2dly. Slender luminous beams, well defined. These often continue a quarter, half, or even a whole minute, apparently at rest, but oftener with a quick lateral motion. 3dly. Flashes pointing upwards, or in the same direction with the beams, which they always succeed. These are only momentary, and have no lateral motion; but they are generally repeated many times in a minute. They appear much broader, more diffuse, and of a weaker light than the beams; they grow fainter till they disappear, and sometimes continue for hours flashing at intervals. 4thly. Arches nearly in the form of a rainbow; these, when complete, go quite across the heavens, from one point of the horizon to the opposite point.

When an aurora happens, these circumstances seem to succeed each other in the following order: first, the faint rainbow-like arches; secondly, the beams; and, thirdly, the flashes. As for the northern horizontal light, it appears to consist of an abundance of flashes or beams blended together, from the situation of the observer.

The beams of the aurora borealis appear at all places to be arches of great circles of the sphere, with the eye in the centre; and these arches if prolonged upwards would all meet at one point.

The rainbow-like arches cross the magnetic meridian at right angles. When two auroræ appear at once, they are concentric, and tend to the east and west; also the broad arch of the horizontal light tends to the magnetic east and west, and is bisected by the magnetic meridians, and where the aurora extends over any part of the hemisphere from the clear part, is half the circumference of a great circle crossing the magnetic meridian at right angles, and terminating in the east and west; moreover,

the beams perpendicular to the horizon, are only those on the magnetic meridian.

That point in the heavens, to which the beams of the aurora appear to converge, at any place, is the same as that to which the South Pole of the dipping needle points at that place.

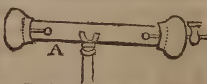
The beams appear to rise above one another in succession; so that of any two beams, that which has the higher base, has also the higher summit.

Every beam appears broadest at, or near the base, and to grow narrower as it ascends; so that the continuation of the bounding lines would meet in the common centre to which that beam tends.

The height of rainbow-like arches of the aurora is estimated to be above the earth's surface about 150 English miles.

The Luminous Conductor.

A very beautiful experiment will illustrate this appearance in the heavens: it is called the luminous conductor. A is a glass tube about 2 feet long capped at both ends with brass, having one of the ends furnished with a stop cock, and screws to



fit into the plate of an air pump. This tube is exhausted of air, and when it is placed in the circuit of the electric fluid, by fixing a chain at each end, which is connected with the positive and negative parts of the machine, the electricity, in passing through it, exhibits a beautiful luminous appearance, very much resembling the Aurora Borealis.

Water spouts are among the phenomena which philosophers have attempted to explain on electrical principles.

A *water spout* is a most formidable phenomenon, and is indeed capable of causing great ravages. It commonly begins by a cloud, which appears very small, and which mariners call the SQUALS; this augments in a little time

nto an enormous cloud of a cylindrical form, or that of a reversed cone, and produces a noise like an agitated sea; sometimes emitting thunders, and lightning, and also pouring down large quantities of rain or hail, sufficient to inundate large vessels, overset trees and houses, and every thing which opposes its impetuosity.

These water spouts are more frequent at sea, than on land; and sailors are so convinced of their dangerous consequences, that when they perceive them at hand, they endeavour to break them by firing a cannon before they approach too near the ship. These meteors have also been known to commit great ravages on land, though, where there is water near, they generally assume the harmless form of a whirlwind.

In accounting for these phenomena upon electrical principles, it is observed, that the effluent matter proceeds from a body actually electrified, towards one which is not so; and the effluent matter proceeds from a body not electrified towards one which is actually so. These two currents occasion two motions analogous to the electrical matters which in this case is composed of particles exhaled from the earth. The particles of vapours, which compose the cloud, are attracted by this effluent matter, and form a cylindrical column, called the DESCENDING water spout. If, on the contrary, the effluent matter is the strongest, it attracts a sufficient quantity of aqueous particles to form gradually into a cloud: this is commonly termed the ASCENDING water spout.

Questions for Examination.

1. What meteorological phenomena does electricity illustrate and account for?

2. What does Beccaria say of the fall of rain? What does he suppose hail to be? and how do clouds of snow differ from clouds of rain?

3. What is the aurora borealis supposed to be? and what are its appearances?

4. How are water spouts accounted for?

SECTION IX.

The identity of Lightning and Electricity.

Dr. Franklin has proved by a variety of experiments, that the lightning of electricity, and the lightning that flashes from the clouds in a thunder storm, are exactly of the same kind, and operate in the same manner.

The particulars, in which lightning and the electric fluid agree, are as follow. 1. Flashes of lightning are generally seen crooked, and waving in the air, as the electric spark, when it is drawn from an irregular body, at some distance. 2. Lightning strikes the highest and most pointed objects in its way, in preference to others; as high hills, and trees, towers, spires, masts of ships, points of spears, and the like. In like manner, all pointed conductors receive or throw off the electric fluid more readily than those that are terminated by flat surfaces. 3. Lightning is observed to take the readiest and best conductor. So does electricity in the discharge of the Leyden phial. For this reason Dr. Franklin supposes, that it would be safer, during a thunder storm, to have one's clothes wet than dry, as the lightning might then in great measure, be transmitted to the ground, by the water on the outside of the body. It is found, he says, that a wet rat cannot be killed by the explosion of the electrical bottle, but that a dry rat may. 4. Lightning causes combustion, so does electricity. Dr. Franklin says, that he could kindle with it, hard dry resin, spirits unwarmed, and even wood. 5. Lightning sometimes dissolves metals: so does electricity. 6. Lightning has often been known to strike people blind. And a pigeon, after a violent shock of electricity, by which the doctor intended to have killed it, was observed to have been struck blind. 7. Lightning destroys animal life. Animals have likewise been killed by the shock of electricity. The largest animals, which Dr. Franklin and his friends had been able to kill, were a hen, and a turkey which weighed about ten pounds.

Thunder is the noise produced by the motion of lightning

The reason why we do not hear the dreadful noise of the thunder, as soon as we see the lightning, is, because sound is longer in arriving to our ears, than light to our sight.

Light moves almost instantaneously. Sound moves no more than 1142 feet in a second.

THERE'S grandeur in the sounding storm,
That drives the hurrying clouds along,
That on each other seem to throng,
And mix in many a varied form;
While bursting now and then between,
The moon's dim misty orb is seen,
And cast faint glimpses on the green.

Beneath the blast the forests bend,
And thick the branchy ruin lies,
And wide the shower of foliage flies;
The lake's black waves in tumult blend;
Rovolving o'er, and o'er, and o'er,
And foaming on the rocky shore,
Whose caverns echo to their roar.

The sight sublime enrapts my thought,
And swift along the past it strays,
And much of strange event surveys,
What History's faithful tongue has taught;
Or Fancy formed, whose plastic skill
The page with fabled change can fill,
Of ill to good, or good to ill.

But can my soul the scene enjoy,
That rends another's breast with pain?
O hapless he, who near the main,
Now sees its billowy rage destroy!
Beholds the foundering bark descend,
Nor knows but what its fate may end
The moments of its dearest friend.

SCOTT.

Questions for Examination.

1. What does lightning appear to be? And how has Dr. Franklin established the identity of lightning and electricity?

2. What is thunder, and at what rate does its sound move?

SECTION X.

Of Animal Electricity.

1. Three fishes have hitherto been discovered to have, whilst living, the singular property of giving shocks, analogous to those of artificial electricity; namely, the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*.

2. The *torpedo* which belongs to the genus of rays is a flat fish, very seldom 20 inches long, weighing not above a few pounds when full grown, and is common in various parts of the sea-coast of Europe.

The electric organs of this animal, two in number, are placed on each side of the gills. Each organ consists of perpendicular columns, reaching from the under to the upper surface of the body, and varying in length, according to the thickness of the fish in different parts. The number of these columns varies in different torpedos, and also in different ages of the animal.

If the torpedo whilst in water, or out of it, but not insulated, be touched with one hand, it generally communicates a trembling motion or slight shock to the hand; but the sensation is felt in the fingers of that hand only. If the torpedo be touched with both hands at the same time, one being applied to its under, and the other to its upper surface, a shock in that case will be received, which is exactly like that occasioned by the Leyden phial. This power of the torpedo is conducted by the same substances which conduct artificial electricity, and is intercepted by the same bodies which are non-conductors of electricity. The cir-

cuit may be formed by several persons joining hands, and the shock will be felt by them at the same time; but no attraction or repulsion was ever observed to be produced by the torpedo.

These shocks depend upon the will of the animal, each effort being accompanied with a depression of the eyes, and motion of the organs.

3. The *gymnotus electricus* has been frequently called the *electrical eel*, on account of its bearing some resemblance to the common eel.

It is found frequently in the great rivers of South America. Its usual length is about three feet; but some of them have been said to be so large, as to strike a man dead with their electric shock. A few of these animals about three feet long, were brought alive to England about 40 years ago, and a great many experiments were made with them. They possess all the properties of the torpedo, but in a superior degree. The spark was visible in a dark room.

4. The *silurus electricus* is found in Africa, but we have a very imperfect account of its properties. Its length seldom exceeds 20 inches.

These animals seem to use the electrical property as a means of self-defence.

Questions for Examination.

1. What three fishes possess the powers of electrical phenomena?
2. Describe the torpedo.
3. Also the gymnotus electricus, or electrical eel.
4. Also the silurus electricus.

SECTION XI.

Medical Electricity.

1. In judging of cases proper to be electrified, experience shews, that in general, all kinds of obstructions, whether

of motion, of circulation, or of secretion, are very often removed or alleviated by electricity.

The same may also be said of nervous disorders; both which include a great variety of diseases.

The application of electricity has also been found a powerful remedy in muscular contractions.

But when any limb is deprived of motion, it must be observed, that the deprivation has not always originated in a contraction of the muscles; but that it is often occasioned by relaxation; thus, for instance, if the hand be bent inwardly, the patient has no power of straightening it, the cause of it may be a weakness of the outward muscles, as well as a contraction of the inward ones.

In such cases, it is difficult, even for anatomists to discover the real cause; but the surest method is to electrify not only those muscles which are supposed to be contracted, but also their antagonists; for, to electrify a sound muscle is by no means hurtful.

Rheumatic disorders of long standing, are relieved, and frequently cured, by only drawing the electric fluid with a point from the part or by drawing sparks from the conductor; the operation should be continued for about four or five minutes, repeating it once or twice every day. When strong shocks are administered, their greatest number should not exceed 12 or 14, except when they are to be given to the whole body in different directions.

2. The instruments, which, besides the electrical machine and its prime conductor, are necessary for the administration of medical electricity, may be reduced to three, viz an electric jar, with Mr. Lane's electrometer; an insulated chair, or an insulated stool, upon which a chair may be occasionly set, and the directors.

Questions for Examination.

1. In what diseases does electricity afford relief?

2. What are the instruments used in medical electricity?

CHAPTER XV.

GALVANISM.

Section I.

General Principles.

1. Galvanism is a method of exciting electricity, or of disturbing the equilibrium of the electric fluid.

It is so called from Galvani, a native of Bologna, who first observed some phenomena which have given rise to this science, and of which he published an account in 1791.

2. The discoveries of Galvani were made principally upon dead frogs. He in the *first place*, discovered that a frog dead and skinned, is capable of having its muscles brought into action by means of electricity, even in exceeding small quantities.

3. *Secondly*, That independent of any apparent electricity, the same motions may be produced in the dead animal, or even in a detached limb, merely by making a communication between the nerves and the muscles, with substances that are conductors of electricity.

If the circuit of communication consists of non-conductors of electricity, as glass, sealing-wax, and the like,

no motion will take place. Similar experiments were also successfully instituted upon other animals; and as the powers seem to be inherent in the animal parts, the power which produces the motion of the muscles in those experiments, were denominated *animal electricity*. But it being now fully ascertained, that by the mere contact of metallic, and other conducting substances, electricity is generated, it is evident, that the muscular motions in the above mentioned experiments were produced by what we shall term the Galvanic action, or Galvanism.

4. It has long been asserted, that when porter, and other liquors, are drank out of a pewter pot, they have a taste different from what they should have, if drank out of glass or earthenware.

5. It has been observed that pure mercury retains its metallic splendour for a long time; but its amalgam with any other metals is soon tarnished or oxidated.

The Etruscan inscriptions, engraved upon pure lead, are preserved to this day; whereas, some medals of tin and lead, of no great antiquity, are much corroded. Works of metal, whose parts are soldered together by the interposition of other metals, soon tarnish about the places where the different metals are joined.

When the copper sheeting of ships is fastened on by means of iron nails, those nails, but particularly the copper, are readily corroded about the place of contact.

6. It has been observed, that a piece of zinc kept in water for a long time will hardly oxidate; but that this effect will soon take place if a piece of silver or copper happens to touch and remain in contact with the zinc whilst immersed in the water.

Questions for Examination.

1. Define Galvanism.
2. Upon what were the discoveries of Galvani first made?
3. How did he operate upon dead animals?
4. What has been observed in drinking out of pewter vessels?
5. Also what has been observed of mercury and the Etruscan inscriptions?
6. What also of zinc kept in water?

Section II.

Combination of Galvanic Circles.

1. The action arising from the combination of three conductors has been examined with success by Volta, who discovered that the slight effect of such a combination may be increased to a prodigious degree *by repeating the combination.*

For instance, if a combination of silver, zinc, and water, produce a certain effect, a second combination (viz. another piece of silver, another piece of zinc, and more water) added to the first, will increase the effect: the addition of a third combination will increase the effect still more, and so on.

2. Previous to the description of the construction of those repeated combinations, which are now generally called *Galvanic batteries*, it will be necessary to state the principal laws, which have been pretty well ascertained with respect to the simple combinations.

Questions for Examination.

1. How has Volta improved Galvani's discoveris?

2. What do we observe previous to our description of the Galvanic batteries?

SECTION III.

The Laws of Galvanic Combination.

1. The conductors of electricity are divided to two principal classes. The first class, called dry and perfect conductors, are metallic substances and charcoal. Those of the second class, or the imperfect conductors, are water and other oxidating fluids. But as the substances of the second class differ in conducting power, much more than those of the first class, so they may be sub-divided into species.

2. *Imperfect Conductors.*

It may be observed, that water holding in solution common air, and especially oxygen gas, is much more active than water deprived of air, by boiling. 2. Water mixed with clay or chalk; 3rd, a solution of sugar: 4th, alcohol; 5th, milk; 6th, mucilaginous fluids; 7th, animal gelatinous fluids; 8th, wine; 9th, vinegar, and other vegetable juices, and acids; 10th, saliva; 11th, mucus from the nose; 12th, blood; 13th, brains; 14th, solution of salt; 15th, soap-suds; 16th, chalk water; 17th, concentrated mineral acids; 18th, strong

alkaline leys; 19th, alkaline fluids; 20th, sulphuret of potash.

Questions for Examination.

1. Into how many classes are the conductors of galvanic electricity divided?
2. How did Volta arrange those conductors?

Section IV.

Simple Combinations of Galvanic Conductors.

1. The simple combinations capable of producing galvanic effects, (viz. to convulse the prepared limbs of a frog, or excite a sour taste upon the tongue, &c.) must consist of three different conductors, for two conductors only will not produce any sensible effect. If the three conductors are all of the first class, or all of the second, then the effect is seldom sensible. In this case, such conductors of the second class, as differ more from each other, are more likely to produce a sensible effect than those of the first class. But a proper active simple combination must consist of three different bodies, viz. of one conductor of one class, and two different conductors of the other class.

Thus, denoting the bodies of the first class by means of large capital letters, and those of the second class by small letters, the combinations of figs. 1 and 2 are active; but those of figs. 3, 4, 5, 6, and 7, are not active; because, those of figs. 3, 4, or 5, consists of two bodies only, and those of

figs. 7 or 8, consists of three bodies; of which two are of the same sort, and, of course, act as a single body.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

2. When two of the three bodies are of the first class, and one of the second, the combination is said to be of the first order; otherwise, it is said to be of the second order.

3. In a single active galvanic combination, or as it is commonly called, a simple galvanic circle, the two bodies of one class must touch each other in more than one point, at the same time that they are connected together at other points by the body of the other class.

Thus, when a prepared frog is convulsed by the contact of the same piece of metal in two different places, then the fluids of those parts, which must be somewhat different from each other, are the two conductors of the second class, and the metal is the third body on the conductor of the first class.

4. If two metals are used, then the fluids of the prepared animals differing but little from each other, may be considered as one body of the second class.

Thus also, when a person drinks out of a pewter jug, the saliva or moisture of his under lip is one fluid or one conductor of the second class, the liquor in the jug is the

other, and the metal is the third body, or conductor of the first class.

5. It seems to be indispensably requisite, that in a simple galvanic circle, the conductor or conductors of one class should have some chemical action upon the other conductor or conductors; without which circumstance the combination of the three bodies will have either no galvanic action at all, or a very slight one. Farther the galvanic action seems to be proportionate to the degree of chemical agency; which seems to shew, that such chemical action is the primary cause of the electric phenomena.

6. The most active galvanic circles of the first order, are when two solids of different degrees of oxidability are combined with a fluid, capable of oxidating at least one of the solids. Thus, gold, silver, and water, do not form an active galvanic circle; but the circle will become active if a little nitric acid, or any fluid decomposable by silver, is mixed with the water.

7. A combination of zinc, silver and water, forms an active galvanic circle, and the water is found to oxidate the zinc, provided the water holds in solution some atmospherical air, as it commonly does, and especially if it contains oxygen gas. But zinc, silver and water, containing a little nitric acid form a more powerful galvanic circle, the fluid being capable of acting both upon the zinc and upon the silver.

8. The most powerful Galvanic combinations of the second order are, when two conductors have different chemical actions on the conductors of the first class, at the same time that they have an action upon each other. Thus, copper, silver or gold, with a solution of an alkaline sulphuret, and diluted nitrous acid, form a very active galvanic circle.

The present state of knowledge relative to this subject, does not enable us accurately to determine the particular powers of all sorts of galvanic combinations: the following lists in Section V. however, contain an useful arrangement of the best combinations, disposed in the order of their powers, and commencing with the most powerful.

Questions for Examination.

1. What are the simplest combinations capable of producing galvanic effects?

2. Describe a combination of the first order.

3. What is the principle of a simple galvanic circle?

4. What is the effect if two metals are used?

5. What is the primary cause of the electrical phenomena here?

6, 7. What are the most attractive galvanic circles of the first order?

8. What also are those of the second order?

SECTION V.

Table of Galvanic Circles of the First Order.

1. These circles consist of two conductors of the first class and one of the second.

Zinc, with gold, charcoal, silver, or copper, tin, iron, or mercury; and water containing a small quantity of any of the mineral acids.

Iron, with gold, charcoal, silver copper, or tin, and a weak solution of any of the mineral acids as above.

Tin, with gold, silver or charcoal, and a weak solution of any of the mineral acids as above.

Lead, with gold or silver, and a weak acid solution, as above.

Any of the above metallic combinations and common water, viz. water containing atmospheric air, or more especially, water containing oxygen gas.

Copper, with gold or silver, and a solution of nitrate of silver and mercury, or the nitric or the acetous acid.

Silver with gold and the nitric acid.

Tables of Galvanic Circles of the Second Order.

2. These circles consist of one conductor of the first class and two of the second.

Charcoal, copper, silver, lead, tin, iron, or zinc, with water or with a solution of any hydrogenated alkaline sulphurets capable of acting on the first three metals only; and a solution of nitrous acid or oxygenated muriatic acid, &c. capable of acting upon all the metals.

Questions for Examination.

1. Repeat the table of the galvanic circles of the first order.
2. Also the table of those of the second order.

SECTION VI.

Theory of the Action of Galvanic Circles.

1. The action of a single galvanic circle seems to be in some measure dependent upon the quantity of surface of contact between the acting bodies. A higher temperature, within certain limits, renders the activity of the circle greater than a lower temperature.

2. The activity of a galvanic circle is not altered by the interposition of such conductors as have no action upon the adjoining conductors of the circle. Thus, if a circle consists of zinc, gold, and water, and if we interpose a piece of iron or silver, or both, between the zinc and the gold, the activity of the circle will not be altered.

Hence it appears that the action of a galvanic circle may be conveyed through extraneous conductors to a considerable distance; but it must be observed, that the activity is weakened by the great length of the conductors, especially if they are of an imperfect nature.

3. When the three bodies which form a galvanic circle of the first order are laid one upon the other, so that the lower and upper ones do not touch each other, then these two extremes are in opposite electric states, viz. the extremity which is next to that metallic surface that touches the body of the second class is positive, and the opposite extremity is negative.

Fig. 9.

Thus, let copper, zinc, and moistened leather, be laid one upon the other, as in the annexed figure, and the upper end W, viz. the moistened leather, will be found possessed of positive electricity; whilst the lower end C, or the copper, will be found negative.

Questions for Examination.

1. On what does the action of a single galvanic circle seem to be dependent?

2. Is the activity of galvanic circles altered by the interposition of conductors that have no action upon the adjoining conductors?

3. In what positions are conductors positive and negative?

SECTION VII.

Galvanic Batteries.

1. Galvanic effects may be increased to almost any degree, by connecting several of the above-

mentioned active combinations, or by a repetition of the same simple galvanic combination, (the most active simple combination forming the most powerful batteries, and *vice versa)*, provided the simple combinations are disposed so as not to counteract each other. Those batteries are said to be of the second or first order according as the simple combinations of which they consist are of the first or second order.

Example. Thus, if a piece of zinc is laid upon a piece of copper, and a piece of moistened card upon the zinc, then a similar arrangement of three other such pieces laid upon them, and and a third arrangement upon this, &c. all in the same order, the whole will form a battery of the first order. But if the arrangement is made by connecting a piece of copper with a piece of cloth moistened with water, the latter with a piece of cloth moistened with a solution of sulphuret of potass, and this again with another piece of copper, &c. the whole will form a battery of the second order.

2. *Sir Humphry Davy* divides the batteries of the second order into the following three classes:

1. The most feeble is composed, whenever single metallic plates or ores are arranged in such a manner that two of their surfaces or ends opposite to each other, are in contact with different fluids, one capable, the other incapable of oxidating the metal. And regular series of such combinations are re-formed.

2. When the single combinations, or elements of the series, consist each of a single plate, or are of a metallic substance capable of acting upon sulphuretted hydrogen, by portions of a solution of sulphurets of potash on one side and water on the other.

3. The most powerful class is formed when metallic sub-

stances, oxidable in acids, and capable of acting on solutions of sulphurets, are connected, as plates with oxidating fluids and solutions of sulphuret of potash, in such a manner that the opposite sides of every plate may be undergoing different chemical changes, the mode of alternation being regular.

Questions for Examination.

1. How may galvanic effects be increased to almost any degree?
2. What then are galvanic batteries, and how does Sir Humphry Davy divide them?

Section VIII.

Laws of Action of Galvanic Batteries.

1. The above-mentioned restriction, viz. that the parts of a battery must not counteract each other, will be easily understood by considering that every simple, but interrupted galvanic combination, has a positive and a negative end, or that in every complete galvanic circle, the electric fluid circulates in *one way only*.

Fig. 10.

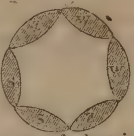
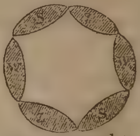


Fig 11.



Example. Thus, if two simple combinations are disposed, as in fig. 10, this arrangement will not have any galvanic power, because the actions of the two simple combinations or the two currents of electricity, are opposed to each other, the two positive ends, being called P, and the two negative ends N. But if those fixed bodies are disposed as in fig. 11, then the combination will be very active, because, according to the hypothesis, the direction

of the electric fluid in each simple arrangement tends the same way, and probably the one accelerates the other.

2. What has been said of the above arrangements of the two simple galvanic combinations must be likewise understood to hold good with respect to the connection of any number of the same, viz. that they must not counteract each other: or if a certain number of them counteract each other, then the remaining only form the active part of the battery.

For instance, if a battery consists of 40 simple combinations, and if twelve of them are placed in a direction contrary to the others, then these twelve will counteract twelve others, and of course the whole battery will have no more power than if it consisted of sixteen combinations properly disposed.

3. This points out a method of comparing the powers of two batteries; for if those batteries are connected in an inverted order, viz. the positive end of one to touch the negative end of the other; then on connecting the two other extremities, or on applying them to proper instruments, the whole power will be annihilated, if the separate batteries had equal power; otherwise the power of the whole will be the excess of the power of the most powerful battery above that of the weakest; and the direction, viz. its being positive or negative, will shew to which battery it belongs.

It must be observed, with respect to the inactive arrangement of figure 10, that if one of the separate bodies Z, is removed, then the remaining five bodies will form an

active combination, for in that case W, W become one body, and S, S likewise act as one body.

4. It is almost superfluous to observe, that (as has been said with respect to simple circles) in a galvanic battery the interposition of conductors that have no particular action, or of the conductors of the same class as the adjoining bodies, does not alter the effect of the battery.

Thus far we have stated the general laws, which have been pretty well ascertained with respect to galvanic combinations. We shall now proceed in the subsequent sections, to describe the practical construction, and the effects of those combinations, especially of the compound arrangements or batteries.

Questions for Examination.

1. What is the first law of action of galvanic batteries?
2. What also is the second law?
3. How then may the powers of two batteries be compared?
4. Is the action of the battery affected by the interposition of any particular conductor?

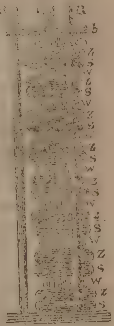
Section IX.

Construction of Galvanic Batteries.

1. The simplicity of single galvanic circles is so great, that nothing more need be said with respect to their construction; for when the three bodies are selected, the operator needs only take care that their contact is perfect.

Fig. 12.

Fig. 13.



2. Galvanic batteries have been constructed of various shapes, and may be endlessly diversified. But the most useful forms are represented by figs. 12, 13, and 14. Those of figs. 12, 13, are more easily constructed; that of fig. 12, however, is the most commodious.

Fig. 14.

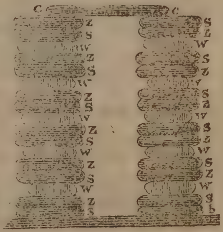
3. The battery fig. 12, consists of several glasses or China cups full of water, or of water containing salt, &c. A plate of zinc and a plate of silver are plunged into the fluid of each cup, excepting the first and last cups; but each of those plates must have a sort of tail or prolongation, by which they are so connected that the silver plate of one cup communicates with the zinc plate of the next, and so on.

4. The battery fig. 13, consists of pieces of silver about the size of half-crowns, pieces of zinc of about an equal size to those of silver, and pieces of card or cloth, leather, or other bibulous substance, a little smaller in diameter than the metallic pieces, and soaked in water or in any other proper fluid. These pieces are disposed in the

order silver, zinc, and wet cloth, as indicated by the letters S, Z, W. The pieces of card or cloth, &c. must be well soaked in the fluids; but before they are applied, they should be squeezed, in order that the superfluous fluid may not run down the outside of the pile, or insinuate themselves between the contiguous pieces of silver and zinc. Those pieces especially if soaked in common water, lose their moisture pretty soon, so that they can hardly serve longer than for a day or two; after which time the pile must be deranged, the metallic pieces cleaned, those of cloth or card, soaked again, and the whole arranged as before.

The three rods, R, R, R, are of glass or of baked wood, and the piece of wood, O, slides freely up or down the rods. This serves to prevent the falling of the pieces.

Fig. 15.



5. When such a battery is to be very powerful, that is to say, when it is to consist of numerous pieces, the best way is to form two or more piles, and to join them by pieces of metal, as C C, in fig. 15, where two piles are joined together, so that *a* is the negative extremity, and *b* is the positive one of the whole arrangement, or of the two piles *a* considered as one.

6. The battery fig. 14, consists of a strong oblong vessel of baked wood or porcelain, about 3 inches deep and as much broad. In the side of this vessel grooves are made opposite to each other, and about one eighth of an inch in depth. In each pair of opposite grooves a double metallic plate, viz. a plate of zinc, and a plate of silver soldered together at their edges are cemented, or the plates may be put in, connected only at their upper parts; by which means the wooden vessel is divided into several cells or

partitions, about half an inch wide, as is indicated by the figure.

The cementation of the metallic pieces into the sides, and the bottom of the wooden vessel, must be so accurate as not to permit the passage of any fluid from one cell into the next. The cement proper for this purpose is made by melting together five parts of resin, four parts of bees-wax, and two parts of powdered red-ochre.

7. Those cells are afterwards filled almost to the top with water, or any other fluid, according to the foregoing table, and thus the whole will form a battery, consisting of various repetitions of silver, zinc, and fluid. Two or more of such batteries may be joined as was said of the preceding battery. See fig. 19, page 430.

It need hardly be observed that instead of zinc, copper and water, other combinations may be made according to the table. At present the last described batteries, are constructed with copper, zinc, and water mixed with a small proportion of Nitric or Muriatic acid.

For the construction of such batteries it is of little consequence whether the materials are pure or slightly alloyed.

8. The action of all these batteries is greatest, when they are first completed or filled with any fluid? and it declines in proportion as the metal is oxidated or the fluid losing its power.

Hence, after a certain time, the fluid must not only be changed, but the pieces must be cleaned, by removing the oxidated surface, which is done either by filing or rubbing them with sand, or sand paper, or by immersing them for a short time in diluted muriatic acid, and then wiping them with a coarse cloth. The metallic pieces of the fig. 15, may be cleaned by the last method and wiped by introducing a stick with a rag into the cells,

9. The energy of galvanic batteries, when the troughs are porcelain, may be restored by merely lifting out the metals, and exposing them to the action of the atmosphere

This much may be sufficient with respect to the con-

struction of simple and compound galvanic arrangements.

Questions for Examination.

1. Is the simplicity of galvanic circles great?
2. How are batteries constructed?
3. Describe the battery fig. 12.
4. Also that of fig. 13.
5. How is this battery made when you wish it to be very powerful as in fig. 14?
6. How also is the battery fig. 15 made?
7. How is this battery to be filled for action?
8. When is the action of all these batteries the greatest?
9. What of the porcelain trough.

SECTION X.

Galvanic Experiments.

1. It is now necessary to state the effects of those combinations. The mode of applying single galvanic circles, and their principal effects, have already been described; yet for the sake of assisting the memory, it will be useful to collect those effects under the four following heads, in explanation of which we shall add such further experiments and observations as could not with propriety be mentioned before.

1. The action of a single galvanic circle affects the organs of living animals, or of animals recently dead, especially when one end of the combination is connected with a nerve, and the other end is connected with a muscle of the same limb.

2 The action may be transmitted through good conductors of electricity, but not through electrics, or through less perfect conductors.

3. It affects the electrometer by the intermediation of other instruments.

2. The action increases or otherwise modifies, the chemical agency of the bodies concerned, upon each other. The limbs of animals, especially of frogs recently dead, are the most sensible instruments of galvanic power; and, in fact, the simplest will affect them, when they will not produce any other decisive electrical effect.

Fig. 16.

The chemical action of bodies upon each other is so much increased by the galvanic arrangement, that some of them are by that means enabled to act upon bodies that otherwise they would have no action upon. Fig. 16 represents a glass tube about four inches long. Two corks are thrust into its apertures A and B. An oblong piece of zinc, C D, is fixed into one of the corks and is made to project within and without the tube. E F G is a silver wire, which being fixed into the other cork, projects with the extremity C within the tube, and its other extremity is bent so as to come near the projecting part of the zinc C. Remove one of those corks, and fill the tubes with water, in which you must mix a drop or two of muriatic acid, then replace the cork; and you will find that the zinc is acted upon by the diluted acid, is oxidated by it, and bubbles of gas are evolved from it; but the silver wire E remains untouched, and no gas whatever is evolved from it. Now if you bend the silver wire F G, so that its end G may touch the zinc at C, then the galvanic circle of silver, zinc, and diluted acid is completed, in consequence of which the diluted acid is enabled to act stronger upon the zinc D which is manifested by the more copious evolution of gas, and is besides enabled to act upon the silver wire: for now you will observe the evolution of gas from the silver wire also. Break the contact between G and C, and the silver-wire E

will cease to yield gas. Form it again, and gas will again proceed from the silver wire.

3. The battery shews all the phenomena of electricity in a very considerable degree. It gives the shock; it affects the electrometer; shews a luminous spark, accompanied with an audible report; it burns metallic and other combustible bodies, and continues in action for a very long time, viz. until the chemical action, between the component parts of the battery is quite exhausted.

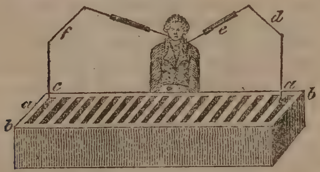
4. The following articles contain a more particular, yet concise, enumeration of those wonderful effects.

Experiment 1.

5. When the Galvanic battery of the first order consists of 20 repetitions of simple combinations, and if with one hand, one extremity of a battery be touched, and the other hand be applied to the other extremity of the battery, a shock will be felt, like that which is communicated by a Leyden phial weakly charged, and it will hardly be felt beyond the fingers, or at most the wrists. This shock will be felt as often as the contact is repeated.

Experiment 2.

Fig. 17.



6. If the hands are continued in contact with the extremities b and a, a slight but continued irritation will be perceived; and when the hand which touches the extremity of the battery is excoriated or wounded, this sensation is disagreeable, and rather painful.

Experiment 3.

7. Instead of one person, several persons may join hands, (well moistened with water) and on completing the curcuit, they will all feel the shock at the same instant. But the strength of the shock is much diminished, by its passing through the several persons, or, in general, by passing through less perfect conductors.

Experiment 4.

8. The shock from a battery consisting of fifty or sixty repetitions, of the most active combinations of the first order, may be felt as far as the elbows and the combined force of five or six such batteries will give a shock much stronger, perhaps, than most men would be willing to receive. The prepared limbs of a frog or other animal, are violently convulsed; but soon exhausted of their irratibility by the action of a galvanic battery, and its action on a person lately executed at Glasgow was the most singularly terrific that medical practitioners had ever witnessed.

Experiment 5.

9. If a wire, proceeding from one extremity of a pretty strong battery, is made to communicate with the inside coating; and a wire which proceeds from the other extremity of the battery is made to communicate with the outside coating of a common large jar or electrical battery; the latter will become weakly, but almost instantaneously; charged in the same manner as if it had been charged by a few turns of a common electrical machine; with this charge you may either give the shock, or effect on the electrometer.

Experiment 6.

10. The spark or the discharge of a galvanic battery, when sent through thin inflammable bodies that are in contact with common air, or oxygen gas, sets them on fire and consumes them with wonderful activity. It fires gunpowder, hydrogen gas, phosphorus, and other combustibles

it renders red-hot, fuses, and oxydates very slender metallic wires, and metallic leaves.

Fig. 18.

Obs. The mode of applying the power of the battery for such purposes is shewn in fig 18. where A B represents a powerful galvanic battery; A C D F, is a wire which communicates with the last plate of the battery at A; B K H G is another wire which communicates with the last plate at B. D E, H I, are two glass tubes, through which those wires pass, and into which they are fastened sufficiently steady. Those tubes serve to move the wires; for if the operator applies his fingers to those tubes, he may move the wires wherever he pleases, without the fear of receiving a shock. If the two extremities F G, are brought sufficiently near to one another, the spark will be seen between them. It is between those extremities that the combustible substances, or the metallic leaf is to be placed in order to be fired or burned.

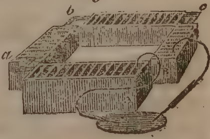
This figure moreover, represents the situation of the wires in the act of inflaming gunpowder.

Experiment 7.

11. A battery consisting of 200 pairs of metallic plates (viz. copper, and zinc each five inches square) melted 23 inches of very fine iron wire.

A platina wire about $\frac{1}{175}$ inch in diameter, was melted into a globule. Fig. 19 is the representation of a compound battery of the same kind, fastened together with iron cramps *a*, *b*, *c*.

Fig. 19.



Obs. Under the exhausted receiver of the air pump, the galvanic battery acts less powerfully than in the open air; but in oxygen gas, it acts with increased power.

Experiment 9.

The flash of light, which appears before the eye of the experimenter, when the eye itself or some other part not very remote from it, is put in the circuit of a galvanic combination, does not appear much greater when a battery is employed than when two plates are applied in the manner which has been already mentioned; but when the battery is used the sensation of a flash may be produced in various ways. If one hand or both be placed in contact with one extremity of the battery, and almost any part of the face brought into contact with the other extremity, the flash will appear very distinctly, the experimenter being in the dark, or keeping his eyes shut. This flash, appears very strong, when a wire which proceeds from one extremity of the batttery, is held between the teeth, and rests upon the tongue, whilst the other wire is held in the hand. In this case the lips and tongue are convulsed, the flash appears before the eyes, and a very pungent taste is perceived in the mouth.

Experiment 10.

13. If any part of the human body, forming part of the circuit of a galvanic battery, is kept sometimes in that situation, the irritation is more or less distinct according to the sensibility of the parts concerned. This application is likely to prove most useful as a remedy in various disorders. It is said that it has already proved most beneficial in deafness and in rheumatisms.

Questions for Examination.

1. State now the effect of the foregoing combinations.
2. How is the increased action of the battery seen on animals?
3. How does it shew the phenomenon of electricity?
4. Repeat the different experiments which shew the wonderful effects of galvanic electricity.

Section XI.

Decomposition of Compound Bodies.

1. The most extraordinary phenomena of a galvanic battery are the chemical effects and the modifications which are produced by it upon the bodies concerned, is upon such as are placed in the circuit. We shall first describe the simplest mode of exhibiting the first of these phenomena, namely the evolution of gas from water, from which the mode of conducting similar experiments is easily derived.

Experiment 1.

Fig. 20.

A B, fig. 20, exhibits a glass tube full of distilled water, and having a cork at each extremity. E F, is a brass or copper wire, which proceeds from one extremity of a galvanic battery, and passing through the cork A, projects within the tube, H Y, is a similar wire, which proceeds from the other extremity of the battery, and comes with its extremity G, within the distance of about an inch or two from the wire F.

In this situation of things, bubbles of gas proceed in a constant stream from the surface of the wire G, which comes from the negative end of the battery; these bubbles of gas, ascending to the upper part of the tube, accumulate by degrees. The gas is the hydrogen and may be inflamed. At the same time the other wire, F, deposits a quantity of oxide in the form of a cloud, whieh generally accumulates in a greenish colour in the water, or on the sides of the tube, and is a perfect oxide of the brass. The wire is readily discoloured and coroded. If the circuit is interrupted the production of gas and of oxide ceases immediately. Complete the circuit, and the production of gas, &c. recommences.

Experiment 2.

4. If two wires of gold or platinum (which are not oxide-

able) are used, the stream of gas will issue from each: the water will be diminished, and the collected gas will be found to be a mixture of hydrogen and oxygen. This mixture explodes violently, when it comes in contact with the flame of a candle.

Experiment 3.

5. When into two small tubes, connected by a moist animal substance, and filled with distilled water, two gold wires are introduced from a large battery in the proper order, oxygen is produced in one quantity of water and hydrogen in the other, nearly in the proportions in which they are required to form water by combustion.

6. All the oxygenated solutions of bodies possessing less affinity for oxygen than nascent hydrogen, are decomposed when exposed to the action of the metal occupying the place of the least oxidable part of the series in the compound circle.

Example. Thus we may produce sulphur from sulphuric acid; and precipitate copper and other metals in the metallic form from their solutions.

Experiment 4.

7. It is well known that hydrogen in its nascent state reduces the oxide of metals. Accordingly, when the tube, fig. 20, is filled with a solution of acetate of lead in distilled water, and a communication is made with the battery, as above described, no gas is perceived to issue from the wire which proceeds from the negative end of the battery; but in a few minutes, beautiful metallic needles are perceived on the extremity of this wire; they soon increase, and assume the form of a fern leaf, or other vegetable. The lead thus separated, is in its perfect metallic state, and very brilliant.

Experiment 5.

8. When a solution of sulphate of copper is employed, the copper is precipitated in its metallic state; but instead of appearing in crystals, it forms a kind of button, which adheres firmly to the end of the wire.

Experiment 6.

9. On making the experiment with a solution of nitrate of silver, the silver is precipitated in the form of a beautiful *metallic brush*, the metal shooting into fine needle-like crystals.

Experiment 7.

10. If iron is immersed in a solution of sulphate of copper, the latter metal will be precipitated in a metallic form, and will adhere to the surface of the former. Upon silver merely immersed in the same solution, no such effect is produced; but as soon as the two metals, viz. the silver and the iron, are brought into contact, in the solution, the silver receives a coating *of copper*.

Query. Recapitulate the foregoing experiments.

Section XII.

1. Little knowledge has yet been obtained concerning the chemical changes taking place in the batteries of the second order. But from experiments, it would appear that they are materially different in the laws of their production from those taking place in the first order.

Example. Thus when single metallic wires with water are placed as series in powerful batteries of the second order, the influence producing oxygen seems to be transmitted by the point in the place of that part of the plate which was apparently incapable of undergoing oxidation, whilst the hydrogen is evolved from that point where the oxidating part of the primary series seemed to exist.

2. The agency of the galvanic influence which occasions chemical changes and communicates electrical charges, is probably, in some measure, distinct from that agency which produces sparks and the combination of bodies.

The one appears to have little relation to surface in compound circles, but to be great in some unknown proportion, as the number of series are numerous. The intensity of the other seems to be as much connected with the extension of the surfaces of the series as with their number.

Example. Thus, though eight series composed of plates of zinc and copper, about ten inches square, and of cloths of the same size, moistened in diluted muriatic acid, give sparks so vivid as to burn iron wire; yet the shocks they produce are hardly sensible, and the chemical changes indistinct; whilst twenty-four series of similar plates and cloths, about two inches square, which occasion shocks and chemical agencies more than three times as intense, produce no light whatever.

The preceding facts corroborate the identity of the galvanic power, and the electricity of a common electrical machine, or that brought down from the clouds; and it reconciles the same principle to animal electricity, viz. the power of the torpedo, gymnotus electricus, &c.—all the phonomena of the animal electricity agree with those of the galvanic battery.

But the most striking circumstance is, that the electric organ of any of the above mentioned fishes, seems to be constructed like a galvanic battery; for it consists of little laminæ or membranes, arranged in columns, and separated by moisture. It seems, in short, to be a galvanic battery, consisting of conductors of the second order only, but undoubtedly of different conducting powers.

Questions for Examination.

1. In what respect do the laws of the second order of batteries differ from those of the first?

2. How does it appear that the agency of the galvanic influence is distinct from that which produces sparks?

3. How may a measure of the intensity of the power of galvanic batteries producing chemical changes, be derived?

CHAPTER XVI.

MAGNETISM.

SECTION I.

General Principles.

1. The natural magnet or loadstone is a hard mineral body, of a dark brown or almost black colour, and when examined, is found to be an ore of iron. It is met with in various countries generally in iron mines, and is of all sizes and forms.

2. The natural loadstone has also the property of communicating its virtues to iron and steel; and when pieces of steel properly prepared are touched, as it is called, by the loadstone, they are denominated artificial magnets.

3. All magnets, whether natural or artificial, are distinguished from other bodies by the following characteristics, which appear to be inseparable from their nature, so that no body can be called a magnet, unless it is possessed of all these properties.

1. A magnet attracts iron.

2. When a magnet is placed so as to be at liberty to move freely in every direction, its ends point towards the

poles of the earth, or very nearly so, and each end always points to the same pole. This is called the *polarity* of the magnet; the ends of the magnet are called poles, viz. north and south poles of the magnet, according as they point to the north and south poles of the earth. When a magnet places itself in this direction it is said to traverse.

3. When the north pole of one magnet is presented to the south of another magnet, these ends attract each other; but if the south pole of one magnet is put to the south pole of another, or the north pole of one to the north pole of another, these ends will repel each other. From these criteria, it is easy to know the names of the poles of a magnetic bar, by applying it near a suspended magnet whose poles are known.

4. When a magnet is situated so as to be at liberty to move itself with sufficient ease, its two poles do not lie in an horizontal direction, but it generally inclines one of them towards the horizon, and of course it elevates the other pole above it. This is called the *inclination* or dipping of the magnet. Any magnets may, by proper methods, be made to impart those properties to iron or steel.

4. A plane perpendicular to the horizon, and passing through the poles of the magnet when standing in their natural direction, is called the *magnetic meridian*; and the angle which the magnetic meridian makes with the meridian of the plane where the magnet stands is called the *declination* of the magnet at that place.

Questions for Examination.

1. What is the natural magnet? what is its history?
2. What are its properties?
3. By what characteristics are all magnets distinguished from all other bodies?
4. What is the magnetic meridian?

SECTION II.

Of Magnetic Attraction and Repulsion.

1. When a piece of iron is brought within a certain distance of one of the poles of a magnet, it is attracted by it, and if the iron is at liberty to move, it adheres to the magnet, and cannot be separated without some force. It appears at first sight that the attraction lies only in the magnet, but experiment proves this attraction to be *mutual*, the iron attracting the magnet as much as the magnet attracts the iron. Place the iron and the magnet upon two separate pieces of cork or wood floating upon water, at a little distance from each other, and it will be found that the iron moves towards the magnet as well as the magnet towards the iron; but if the iron be kept steady, the magnet will move towards it.

This attraction is strongest at the poles of a magnet, and it diminishes in proportion to the distance of any part from the poles, so that in the middle between the poles there is no attraction. This may be easily perceived by presenting a piece of iron to various parts of the surface of a magnet.

3. As magnetic attraction takes place only between poles of different magnets, that is, the north pole of one magnet attracts the south pole of another; consequently magnetic repulsion acts only between poles of the same name of different magnets. Thus, if the north pole of one magnet is opposed to the north pole of another magnet, or if the south pole be opposed to the south pole of the other, then those magnets will repel each other, and that with nearly as much force as the poles of different names would attract each other.

2. The attractive power of a magnet may be very much improved by suspending a weight of iron to it, by its power of attraction, which may be gradually increased; and also by keeping it in a proper situation, viz. with its north pole towards the north, and consequently its south pole towards the south. On the contrary this power is diminished by an improper situation, and by keeping too small a piece of iron, or no iron at all appended to it.

Obs. In the northern parts of the world the north pole of a magnet has more power than its south pole; whereas the contrary effect has been said to take place in the southern parts.

3. Amongst the natural magnets, the smallest generally possess a greater attractive power in proportion to their size than those of a larger bulk.

It frequently happens that a natural magnet, cut from a large loadstone will be able to lift a greater weight of iron than the original loadstone itself.

As both magnetic poles together attract a much greater weight than a single pole, and as the two poles of a magnet generally are in opposite parts of its surface, in which case it is almost impossible to adapt the same piece of iron to them both at the same time; therefore it has been commonly practised to adapt two broad pieces of soft iron to the poles of the stone, and to let them project on one side of the stone; for those pieces become themselves magnetic while thus situated, and then the piece of iron or weight may be easily adapted. Those two pieces of iron are generally fastened upon the

stone by means of a brass or silver box. The magnet in this case, is said to be armed, and the two pieces of iron are called the *armature*. Fig. 2, represents an armed magnet, where A B is the loadstone; C D, C D, are the armature, or the two pieces of soft iron, to the projections of which, D, D, the iron weight E, is to be applied. The dots E, L, *d*, L, *d*, represent the brass box, with a ring at E, by which the armed magnet may be suspended.

2. Artificial magnets, when straight, are sometimes armed in the same manner; but they are frequently made in the shape of a horse-shoe, having their poles at the truncated extremities, as at N and S, (fig. 2) in which shape it is evident that they want no armature.

Questions for Examination.

1. What is understood by magnetic attraction? Between what poles does magnetic attraction take place?
2. How is the magnetic attraction diminished?
3. Between what does repulsion take place?
4. How is it proved that iron in contact with a magnet becomes itself attractive?
5. How may the attractive power of the magnet be improved?
6. Which magnets possess most attractive power?

SECTION III.

The Polarity of the Magnet.

1. Every magnet has a south and north pole, and a line drawn from one end to the other, passes through the centre of the magnet. Here it must not be understood, that the polarity of a magnet resides only in two points of its surface; for, in

reality, it is the one half of the magnet that is possessed of one kind of polarity, and the other half of the other kind of polarity; the poles then are those points in which that power is the strongest.

The line drawn from one pole to the other, is called the axis of the magnet; and a line formed all round the surface of the magnet, by a plane which divides the axis into two equal parts, and is perpendicular to it, is called the *equator* of the magnet.

2. It is the polarity of the magnet that renders it so useful to navigators. When a magnet is kept suspended freely, so that it may turn north and south, the pilot by looking at the position of it can steer his course in any required direction.

Example Thus, if a vessel is steered towards a certain place which lies exactly westward of that from which it set out, the navigator must direct it so that its course may be always at right angles with the direction of the magnetic needle of his compass, keeping the north end of the magnet on the right hand side, and, of course, the south end on the left hand side of the vessel; for, as the needle points north and south, and the direction is east and west, the intended course of the vessel is perpendicular to the position of the magnet. A little reflection will shew how the vessel may be steered in any other direction. An artificial magnet fitted up in a proper box for the purpose of guiding the direction of a traveller, is called a *magnetic needle,* and the whole together is called the *mariner's compass.*

Although the north pole and the magnet in every part of the world when suspended, points towards the northern parts, and the south pole toward the southern parts, yet its ends seldom point exactly towards the ends of the earth.

The angle in which it deviates from due north and south is called *the angle of declination*, or the *declination of the magnetic needle*, or the *variation of the compass*; and this declination is said to be east or west, according as the north pole of the needle is eastward or westward of the astronomical meridian of the place.

4 This deviation from the meridian is not the same in all parts of the world, but is different in different places; and it is even continually varying in the same place.

Obs. The declination from the meridian, and the variation of this in different parts of the world, are very uncertain, and cannot be foretold: actual trial is the only method of ascertaining them.

Before *volcanic eruptions* and *earthquakes*, the magnetic needle is subject to very extraordinary movements.

It is also agitated before, and after the appearance of the aurora borealis.

Questions for Examination.

1. Explain to me what is meant by the polarity of the magnet.
2. Whence arises its usefulness to man?
3. How are artificial magnets sometimes armed? and what are they then called?
4. What is meant by the declination of the magnet needle?

SECTION IV.

The magnetical inclination, or dip of the Needle.

1. If a needle which is accurately balanced, and suspended so as to turn freely in a vertical plane, is rendered magnetic, the north pole will be de-

pressed, and the south pole elevated above the horizon: this property is called the *inclination or dip of the needle*, and was discovered by Robert Norman, about the year 1576.

Illus. Take a globular magnet, or which is more easily procured, an oblong one, like S. N. fig. 3; the extremity N, of which is the north pole; the other extremity, S, is the south pole, and A, is its middle or equator; place it horizontally upon a table C D, then take another small oblong magnet, *n s*, viz. a bit of steel wire, or a small sewing needle magnetized, and suspend it by means of a fine thread tied to its middle, so as to remain in an horizontal position when not disturbed by the vicinity of iron, or other magnet. Now, if the same small magnet being held by the upper part of the thread be brought just over the middle of the large magnet within two or three inches of it, the former will turn its south pole, *s*, towards the north pole, N, of the large magnet, and its north pole, *n*, towards the south pole S, of the large one. It will be farther observed, that the small magnet while kept just over the middle of the large one, will remain parallel to it; for since the poles of the small magnet are equally distant from the contrary poles of the large magnet, they are equally attracted. But if the small magnet be moved a little nearer to one end than to the other of the large magnet; then one of its poles, viz. that which is nearest to the contrary pole of the large magnet will be *inclined downwards*, and of course the other pole will be *elevated* above the horizon. It is evident that this inclination will increase according as the small magnet is placed near to one of the poles of the large one, because the attraction of the nearest will have more power upon it. If the small magnet be brought just opposite to one of the poles of the large magnet, it will turn the contrary pole towards it, and will place itself in the same straight line with the axis of the large magnet.

This simple experiment will enable the reader to comprehend easily the phenomena of the *magnetic inclination*, or of the dipping needle upon the surface of the earth; for it it only necessary to imagine that the earth is a large magnet (as in fact it appears to be) and that any magnet, or magnetic needle commonly used, is the small magnet employed in the above mentioned experiment.

2. A Magnetic Needle constructed for the purpose of showing this property is called a *dipping needle*, and its direction in any place is called the *Magnetic line*. When it was said that the North Pole was possessed of a South Polarity, it was only meant that it had a Polarity contrary to that end of the Magnetic Needle, which is directed towards it.

If the Geographical Poles of the earth, (that is the ends of its axis) coincided with the Magnetic Poles, or even if the Magnetic Poles were constantly at the same distance from them; the *inclination* of the Needle, as well as its declination would always be the same; and hence by observing the direction of the magnetic needle, in any particular place, the latitude and longitude of that place might be ascertained; but this is not the case, for the magnetic poles of the earth do not coincide with its real poles, and they are also constantly shifting their situation; hence the magnetic needle changes continually and irregularly, not only in its horizontal direction, but likewise in its inclination, according as it is removed from one place to another, and also while it remains in the very same place.

Questions for Examination.

1. Explain what is called the dip of the needle.
2. What is the magnetic line?

SECTION V.

To communicate the Magnetic Properties to Steel or Iron.

1. There are various methods of giving the magnetic power to steel or iron. In some cases it appears to be acquired without the use of another magnet.

If you take a bar of iron three or four feet long, and hold it in a *vertical position*, you will find the bar is magnetic and will act upon another magnet; the lower extremity of the bar attracting the South Pole and repelling the North Pole. If you invert the bar the polarity will be instantly *reversed*; the extremity which is now lowest, will be found to be the North Pole, and the other extremity the South Pole.

2. Bars of iron that have stood in a perpendicular position are generally found to be magnetic; as fire-irons, bars of windows, &c.

If a long piece of hard iron or steel is red hod, and then left to cool in the direction of the magnetic line it becomes magnetic.

Striking an iron bar with a hammer, or rubbing it with a file, while held in this direction makes it magnetic. An electric shock produces the same effect; and lightning often renders iron magnetic.

Obs. A magnet cannot communicate a degree of magnetism stronger than that which itself possesses; but two or more magnets joined together, may communicate a greater power to a piece of steel, than either of them possesses singly; hence we have a method of constructing very powerful magnets, by first constructing weak artificial magnets, and then joining them together to form a

compound magnet, and to act more powerfully upon a piece of steel.

3. A magnet bent, so that the two ends almost meet, is called a *horse shoe-magnet*.

To render it magnetic, place a pair of magnetic bars against the ends of the horse shoe, with the south end of the bars against that of the horse-shoe, which is intended to be the north, and the north end of the bar to that which is to be the South, the contact or lifter of soft iron, to be placed at the other end of the bars. Also rub the surfaces of the horse-shoe, with a pair of bars placed in the form of a compass, or with another horse-shoe magnet turning the poles properly to the poles of the horse-shoe magnet, being careful that these bars never touch the end of the straight bars.

If the bars are suddenly separated from the horse-shoe magnet, its force will be considerably dimished, to prevent this, slip on the *lifter*, or support to the end of the horse-shoe magnet, but in such a manner however, that it may not touch the bars; the bars may then be taken away and the support will slide to its place. Magnetism is best communicated to compass-needles by the two following methods.

Procure a pair of magnetic bars, not less than six inches in length. Fasten the needle down on a board, and with a magnet in each hand, draw them from the centre upon the needle outwards; then raise the bars to a considerable distance from the needle, and bring them perpendicularly down to the centre, and draw them over again. This operation, repeated about twenty times will magnetise the needle, and its ends will point to the Poles, contrary to those that touched them, and vice versa for the other end.

In communicating magnetism, it is best to use weak magnets first, and those that are stronger afterwards; but care must be taken *not to use weak after strong magnets.*

Questions for Examination.

1. Explain how the magnetic properties are communicated to iron and steel.

2. Describe the horse-shoe magnet; and explain its construction.

SECTION VI.

The Construction and Use of the principal Magnetical Instruments, &c.

Magnetic instruments may be reduced to three principal heads, viz. 1st. the Magnets or Magnetic bars which are necessary to magnetise needles of compasses or such pieces of steel, iron, &c. as may be necessary for divers experiments; and which have already been sufficiently explained in the preceding pages.

2. The compasses, such as are used in navigation, and for other purposes, which are only magnetic needles accurately suspended in boxes, and which according to the purposes for which they are particularly employed, have several appendages or differ in size, and in accuracy of division, &c. whence they derive the names of *Pocket Compasses, Steering Compasses, Variation Compasses, and Azimuth Compasses.*

The Dipping Needle.

3. The Magnetic Needles which are commonly used at sea, are between four and six inches long, but those which are used for observing the daily variation, are made a little longer, and their ex-

tremities *point the variation upon an arch or circle properly divided and affixed to the box.*

4. The best shape of a Magnetic Needle is represented in figs. 4 and 5; the first of which shews the upperside, and the second shews a lateral view of the needle, which is made of steel, having a pretty large hole in the middle, to which a *conical piece of agate* is adapted by means of a brass piece (O) into which the agate is fixed.

The apex of this hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the Needle, being property balanced, turns very nimbly. For common purposes, these Needles have a *conical perforation* made in the *Steel itself*, or in a piece of brass which is fastened in the middle of the Needle.

5. The Mariners' Compass or compass generally used on board of ships, is represented in the annexed figures. The box which contains the card or fly with the Needle, is of a circular form, and is made either of Wood, Brass, or Copper.

Fig. 1.

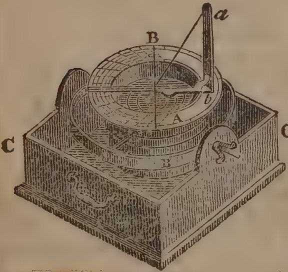
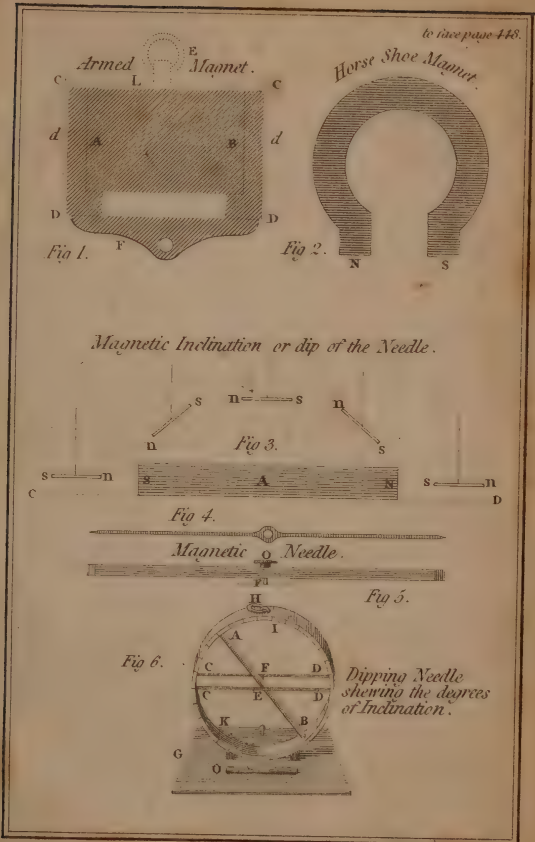


Fig. 2.



Engraved for Pinnock & Maunders Elements of Nat. & Ex. Phil. by Sid^y Hall.

Illus. 1. Fig. 1. is an azimuth compass; fig 2 is the common mariner's compass. The azimuth compass differs from the common compass only in this, that the circumference of the card A B. or box is divided into degrees; also to the box is fitted an index with two sights, which are upright pieces of brass placed diametrically opposite to each other, having a slit down the middle of them, through which the sun or a star is to be viewed at the time of observation. C C is the frame of the box, and *a b* is one of the perpendicular pieces of brass; and the use of this instrument is to take the bearing of any celestial object when it is above the horizon, in order to find from the magnetical azimuth, or amplitude, the variation of the needle.

2. The common compass, fig. 2, is suspended within a square wooden box, by means of two concentric circles, called *gimbalds,* so fixed by cross axes to the two boxes, that the inner or Compass box, shall retain an horizontal position in all motions of the ship, whilst the outer or square box is fitted with respect to the ship. The compass box is covered with a pane of glass, in order that the motion of the card may not be disturbed by the wind.

What is called the card, is a circular piece of paper, which is fastened upon the Needle and moves with it. Sometimes there is a slender rim of Brass, which is fastened to the extremities of the Needle and serves to keep the card stretched.

Compass Card.

The outer edge of the card is divided into 360 equal parts or degrees, and within the circle of those divisions, it is again divided into 32 equal parts, or arcs, which are called the *Points of the Compass*, or *Rhumbs*, each of which is often subdivided into *Quarters*. The initial letters N E S, are annexed to those Rhumbs to denote the North, East, &c. The middle part of the card is mostly painted with a sort of star, whose rays terminate in the above men-

tioned divisions. To avoid confusion, these letters, &c. are not drawn in the figure.

The Dipping Needle though of late much improved, is however still far from perfection. The general mode of constructing it is to pass an axis quite through the Needle, to let the extremities of this axis like those of the beam of a balance rest upon its supports, so that the Needle may move itself vertically round, and when situated in the Magnetic meridian it may place itself in the Magnetic line.

The *degrees of Inclination* are shewn upon a divided circle, in the centre of which the needle is suspended. Fig. 6. represents a Dipping Needle of the simplest construction, A B, is the Needle, the axis of which F E, rests upon the middle of two lateral bars C D, C D, which are made to the frame that contains the divided circle A I B K. This machine is fixed on a stand G, but when used at sea it is suspended by a ring H, so as to hang perpendicularly. When the instrument is furnished with a stand, a spirit level O, is generally annexed to it, and the stand has three screws, by which the instrument is situated, so that the centre of the needle, and the division of 90 on the lower part of the divided circle, may be exactly in the same time perpendicular to the horizon.

Questions for Examination.

1. To how many classes may magnetical instruments be reduced?
2. Describe the magnetic needle used at sea.
3. What is the best shape of a magnetic needle?
4. Describe the construction of the mariner's compass.

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